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ARCHIVES OF SURGERY

VOL. 9 SEPTEMBER, 1924 No. 2

RESULTS OF SURGERY AND OF SURGERY COMBINED WITH ROENTGEN-RAY TREATMENT IN EXOPHTHALMIC GOITER *

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AND

J. H. MEANS, M.D.

BOSTON

In the course of observation of cases of exophthalmic goiter at the Massachusetts General Hospital, data have been collected on cases which have been treated both by roentgen ray and by surgical procedures. From this clinic, Holmes and Merrill,[1] and Holmes and Means [2] have published the results of roentgen-ray treatment in this condition. Means and Aub [3] and E. P. Richardson [4] have made a comparison between the results of roentgen-ray treatment and surgery. C. A. Porter [5] has reported the late results of his experience in the surgical treatment of exophthalmic goiter, based in part on cases treated in this clinic.

The question, however, as to whether surgical treatment is favorably affected by previous roentgen-ray treatment, or whether partial operations might increase the effect of roentgen-ray treatment in exophthalmic goiter has not been discussed in detail. Although the data at hand are meager, they are presented at this time, since the use of iodin in the form of Lugol's solution, as suggested by Plummer and Boothby, is being studied in this clinic. This drug modifies, temporarily at least, the course of the disease, and thus introduces an additional factor, and

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* From the surgical services, roentgen-ray department and the medical laboratories of the Massachusetts General Hospital. The metabolism studies were aided in part by a gift from Dr. William Norton Bullard.

1. Holmes, G. W., and Merrill, A. S.: Treatment of Thyrotoxicosis by Means of the Roentgen Ray, J. A. M. A. **73**:1693 (Nov. 29) 1919.

2. Means, J. H., and Holmes, G. W: Further Observations on the Roentgen-Ray Treatment of Toxic Goiter, Arch Int. Med. **31**:303-341 (March) 1923.

3. Means, J. H., and Aub., J. C.: A Study of Exophthalmic Goiter from the Point of View of the Basal Metabolism: With Remarks Concerning the Effect of Various Forms of Treatment, J. A. M. A. **69**:33-37 (July 7) 1917.

4. Richardson, E. P.: Relative Value of Surgery and Roentgen Ray in the Treatment of Hyperthyroidism, J. A. M. A. **80**:820-825 (March 24) 1923.

5. Porter, C. A.: Analysis of My End Results in Thyroid Surgery, Surg., Gynec. & Obst. **36**:621 (May) 1923.

occasionally a striking one, which tends to obscure the part actually played by surgery or by roentgen-ray treatments in the patient's general condition and metabolism.

SCOPE OF PAPER

When surgery and roentgen-ray treatment are used together in the treatment of exophthalmic goiter, there are various points of practical importance to be considered. The first of these is the question as to whether roentgen-ray treatment tends to diminish the risk of subsequent operation. The second is the effect of the roentgen ray on the technical difficulty of a later operation. These two points can be discussed only in general. This paper is more directly concerned with these three questions: 1. Does previous roentgen-ray treatment increase the efficacy of preliminary or partial operative procedures? 2. Do preliminary operations, particularly ligations of the superior thyroid arteries, increase the effectiveness of subsequent roentgen-ray treatment? 3. Do patients who have undergone roentgen-ray treatment show any difference in the later operative results, particularly in regard to an increased tendency to myxedema following the complete operation of subtotal thyroidectomy? In addition, the data give some evidence, which will be discussed, as to the relative effectiveness of various operative procedures, and the time which should elapse after incomplete operations before further surgery is undertaken.

Our views in regard to the effect of the roentgen ray on the operative risk may be summarized thus: We have no reason to believe that roentgen-ray treatment for a few months in early selected cases increases the operative risk. Certain patients who show a drop in metabolism and pulse, and an increase of weight during roentgen-ray treatment, are distinctly better risks than they were at the time the treatment was begun. We cannot show, however, that the cases which prove resistant to roentgen-ray treatment require fewer preliminary operations or have a lower operative mortality than the cases in this clinic treated entirely by surgery. A considerable proportion of the patients treated by roentgen rays do not undergo surgery, and to this extent the immediate total operative risk is reduced.

In regard to the technical difficulty of the operation itself, it is the opinion of one of us (E.P.R.), confirmed by C. A. Porter, that the cases treated by roentgen ray in this clinic show no noteworthy increase in operative difficulty, and that therefore we need not consider this aspect of the situation in relation to the use of the roentgen ray.

DEFINITION OF METHODS

Cases of exophthalmic goiter only are considered in this paper; cases of adenomatous goiter with hyperthyroidism have been omitted. A

majority of the cases have been studied and treated by the thyroid committee. In most of the earlier cases operation was performed by Dr. C. A. Porter, to whom we are indebted for permission for their inclusion in this report. The roentgen-ray treatment was carried out under the direction of Dr. G. W. Holmes. The only basis for the selection of cases has been the frequency of metabolism determinations. Many cases could not be used on account of too recent operation, too short interval between operations, or an insufficient number of observations of metabolism, pulse and weight. Otherwise, no cases have been omitted, except when noted. Cases having had three or more roentgen-ray exposures are grouped with roentgen-ray cases. While we know that three exposures are insufficient to show the full response to the roentgen rays, they may be considered as possibly influencing the course of the disease. One or two treatments are ordinarily without a clearly marked effect. It should be noted further that the patients operated on after roentgen-ray treatment have shown themselves resistant to this form of treatment, and therefore no conclusions as to its general effectiveness can be drawn from this group of cases.

The terms used in describing operations require some definition. Ligation of the superior thyroid arteries ordinarily means a ligation of the arteries with all structures accompanying them, veins, lymphatics, etc., as they enter the superior pole of the gland. This operation is usually performed on one side at a time. Ligation of the inferior thyroid arteries has not been done in this clinic as a therapeutic procedure in itself, since it had been considered too extensive an operation to justify the amount of benefit likely to be obtained. In cases in which a doubt existed, after ligation of the superior thyroid arteries, as to the patient's ability to undergo a subtotal thyroidectomy, a hemithyroidectomy has been performed instead of ligation of the inferior thyroid arteries, as being more likely to justify the operative risk by a definite improvement. By subtotal thyroidectomy is meant removal of the whole gland, except enough of the posterior part of both lobes to maintain thyroid function. By hemithyroidectomy is meant a similar removal of one side, but the term is used to include a few cases of complete removal of one lobe.

The effectiveness of different operative procedures has been judged by variations in the metabolism, weight and pulse. A reduction in pulse and basal metabolic rate, accompanied by a gain in weight, is so regularly accompanied by improvement in the general condition, as observed clinically, that we feel justified in using these observations as a convenient measure, which may be presented visually, of fluctuations in the course of the disease. While a return of these observations to normal for the individual is not always evidence of a clinical cure on account of secondary organic damage, particularly cardiac, which may have been

caused by the disease, an elevation above normal for pulse and metabolism is satisfactory evidence that the disease is still active, and the degree of elevation is essentially proportional to the degree of activity. These variations are shown by charted curves of the arithmetical mean for observation of pulse, metabolism and weight, all constructed on the same plan. The starting point is the last metabolism determination before operation, and preceding it by a short but varying interval. The time interval is two weeks, and the weight is recorded in percentages of the weight previous to the operation discussed. Cases in which there was an increase of weight due to edema are omitted. In many instances, the observations are not sufficiently frequent to give the true representation of the course of the disease. They give, however, a close approxi-

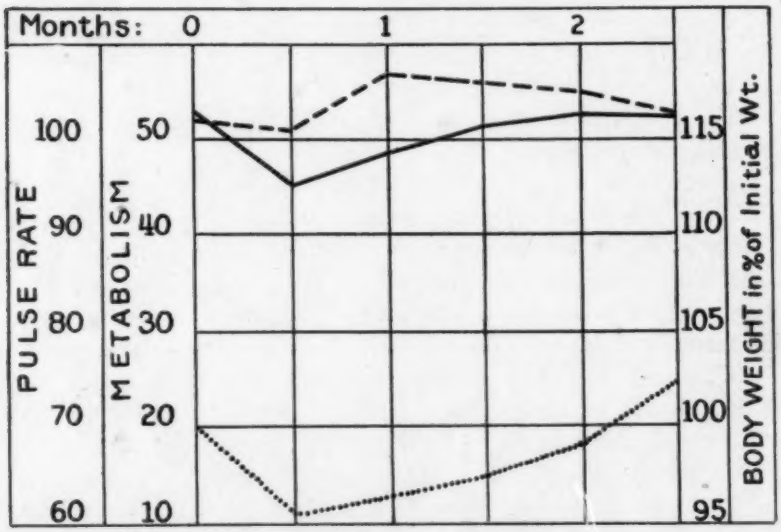

Chart 1.—Effect of ligation of the superior thyroid artery in eleven cases of exophthalmic goiter without previous roentgen-ray treatment, followed two and one half months. In this and the accompanying charts, the solid line denotes metabolism; the interrupted line, the pulse, and the dotted line, the weight. The curves begin at the time of the operative procedure. The averages used as a starting point are those obtained at the last metabolism determination before the operation discussed.

mation. Cases may occur in two or more charts, as the patients successively underwent double ligation, hemithyroidectomy and a second hemithyroidectomy which completed a subtotal thyroidectomy.

In discussing results, "cured" is used in the sense of relieved of any evidence, clinical or metabolic, that activity of the exophthalmic goiter still exists, although the patient may complain of symptoms, particularly cardiac, which are end-results, or of trouble not at all connected with the

disease. "Clinically well" means that the patient feels subjectively well, and is restored to normal activity, although the metabolic rate may be high enough to suggest persistence of the disease, or low enough to bring myxedema into question. "Thyrotoxic" is used without etiologic significance as a convenient term to denote persistence of the symptom-complex of exophthalmic goiter.

EFFECT OF LIGATION OF THE SUPERIOR THYROID ARTERIES

Chart 1 shows the effect of ligation of the superior thyroid arteries in eleven cases untreated by the roentgen ray. It shows the most marked drop in metabolism at the end of two weeks. This is accompanied by a definite decrease in weight, associated with the disturbance caused by

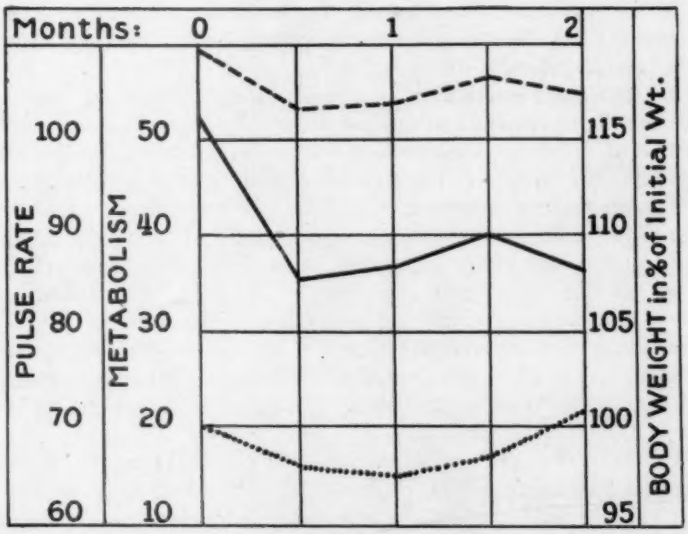

Chart 2.—Effect of ligation of the superior thyroid arteries in seven cases after roentgen-ray treatment, followed two months.

operation and stay in the hospital. The metabolism then shows a rise, and remains at almost the preoperative level to the end of two and a half months. The pulse tends to be slightly more rapid than before operation. The weight increases steadily from its low point and is rising sharply at the end of the period. The final effect of ligation in these cases is far from striking. In no case did it promise a curative effect. The results are much less definite than those reported from other clinics. They serve, however, as a basis for comparison in our own work. The final variation of importance is the tendency of the group as a whole to gain weight toward the end of two and a half months' period.

Chart 2, based on seven cases having double superior ligation following roentgen-ray treatment, shows somewhat similar curves. The drop in metabolism is more marked and better sustained. The weight shows a loss, followed by a similar tendency to gain toward the end of two months. Judged strictly from these charts, ligation of the superior thyroid arteries would appear to be slightly more effective following treatment by the roentgen ray, but this variation may well be due to the small number of cases. In one case, not included in Chart 2, the patient was apparently cured by these measures, and the case reported in detail.

Mrs. E. H. W., aged 22, married, admitted to the hospital, April 20, 1922, had a typical moderately severe case of exophthalmic goiter of one year's duration. She had had amenorrhea for one year.

April 21: The basal metabolism was +40; pulse, 118; weight, 46.8 kg.

April 28: Tonsillectomy was performed.

May 17: The patient was discharged. The basal metabolism was —35; pulse, 110; weight, 46.5 kg. Roentgen-ray treatment was begun, four treatments being given; the last, August 9.

July 19: The basal metabolism was +48; pulse, 120; weight, 46.6 kg.

September 13: Operation was advised on account of lack of improvement.

September 20: The basal metabolism was +48; pulse, 110; weight, 50 kg.

October 3: The patient was readmitted. There was no subjective improvement from roentgen-ray treatment.

October 4: The basal metabolism was +48; pulse, 130; weight, 50 kg.

October 9: Ligation of the right superior thyroid artery was performed.

October 17: The basal metabolism was +13; pulse, 84; weight, 48.3 kg. Ligation of the left superior thyroid artery was performed.

October 20: The basal metabolism was +11.5; pulse, 96; weight, 48.3 kg.

November 1: The basal metabolism was +5; pulse, 89; weight, 51 kg.

December 5: The basal metabolism was —10; pulse, 74; weight, 55 kg. The patient had apparently recovered.

Jan. 5, 1923: The basal metabolism was —8; pulse, 71; weight, 56 kg. The patient returned to work.

March 11: The basal metabolism was —6.5; pulse, 74; weight, 56 kg. The patient felt well. The amenorrhea continued.

June 20: The basal metabolism was —17.5; pulse, 80; weight, 60.5 kg.

The sudden metabolic drop in this case, occurring after the first ligation and continuing after the second, is contrary to our usual experience, and we are inclined to attribute the benefit to a somewhat delayed action of the roentgen ray, or to some factor other than the surgical intervention.

While the total effect of ligation, particularly when Chart 1 is considered, seems slight, the value of the procedure should not be judged solely on this basis. The patient has gained confidence in regard to hospital surroundings and to operation, and faces a later thyroidectomy with composure. Her resistance to operation has been tested, and the danger of a more extensive procedure can be judged with increased

accuracy. Finally, if operation is undertaken two or three months after ligation, it is done in the great majority of cases while the patient is gaining weight, and to this extent at least during a remission of the disease.

In this clinic, patients have frequently had a thyroidectomy performed during the first month following ligation, a period which corresponds, as has been shown, to the maximum drop in metabolism. These cases have not been included in the charts since the period following operation is too short. This early drop in metabolism is ordinarily accompanied by a considerable loss of weight. Under these conditions it seems to us unlikely that the basal metabolism alone is a satisfactory measure of the patient's clinical improvement. It is not reasonable to suppose that a patient already below normal weight, who loses 5 per cent. more weight following operative procedure, is then in good condition to undergo further surgery, even if the maximum reduction in metabolism occurs at this time. It would seem safer to assign more importance to the patient's weight, and to postpone thyroidectomy for two or three months after ligation.

If, as we believe, roentgen ray influences favorably the course of exophthalmic goiter in certain cases, it is reasonable to inquire whether its effect might not be greater after the disturbance produced in the gland through changes in its circulation, nerve supply or otherwise, following ligation of the superior thyroid arteries. Our cases illustrating this point are few and do not lend themselves to charting. The observations therefore are recorded in Table 1.

Of the six cases reported, in two, Cases 1109 and 606, the patients were essentially unimproved, and underwent further operation. One patient (Case 359) is thyrotoxic after four years, the improvement shown being due possibly as much to time as to treatment. In Case 407, the patient was nearly well when last seen, after vigorous roentgen-ray treatment, and may be classed as improved. It is only fair to say that further operation would be urged in both these cases at the present time after four or five roentgen-ray treatments had proved ineffective. In Case 560, the patient may be classed as cured, but the relative part played by surgery and by roentgen ray must remain in doubt. In Case 1964, the patient is apparently cured, but here the use of Lugol's solution is a factor. We can only say that these results are not better than the results of roentgen-ray treatment alone in this clinic, as published elsewhere,[2] which show one third of the patients apparently cured; one third, benefited, and one third, unimproved. These six cases show no evidence that the effectiveness of roentgen-ray treatment is increased by ligation of the superior thyroid arteries.

TABLE 1.—*Data on Cases in Which Roentgen-Ray Treatment Was Given Following Ligation of the Superior Thyroid Arteries*

Case (Lab. No.), Age; Duration of Disease	Date	Metabolism	Pulse	Weight, Kg.	Operation	Roentgen Ray Treatment	Remarks
1109, Mr. F. C. J., aged 43; 3 years	8/25/21	+59	106	62			
	8/29/21	+46	86	61	8/30/21, ligation right superior artery 9/10/21, ligation left superior artery		
	9/19/21	+55	91	56.3			11/7/21, admitted to hospital
	11/ 8/21	+77	110	62.5			11/18/21, operation omitted; reacted badly in operating room; rest in bed; roentgen ray advised
	11/15/21	+67	100	58			
	11/23/21	+59	101	53.5		11/25/21	
	11/28/21	+59	74	53.5		12/ 2/21	
	12/12/21	+42	100	52		12/ 9/21	12/12/22, discharged from hospital
						1/11/22	
						2/23/22	
	3/16/22	+66	110	62		3/16/22	
	4/ 5/22	+51	104	62.5		4/ 5/22	
	4/26/22	+84	116	63	4/29/22, right hemithyroidectomy		4/26/22, not improving; roentgen ray treatment omitted; operation advised (Compare Table 4)
606, Mrs. H. H., aged 26; 5 months	5/ 5/20	+48	108	48.5			
	5/20/20	+51	120	47	6/5/20, ligation right superior artery	6/ 3/20	
	6/10/20	+33	140	45.4	6/18/20, ligation left superior artery		
						6/22/20	
	6/25/20	+44.5	132	45		7/21/20	
						9/ 9/20	
						9/29/20	
	10/ 7/20	+39	128	58.5	10/11/20, right hemithyroidectomy		10/7/20, some subjective improvement and gain in weight, but disease still active; further operation advised
359, Miss A. H., aged 26; 3 years	2/14/19	+54	104	44	2/25/19. ligation right superior artery		
	3/24/19	+39	88	43	3/11/19, ligation left superior artery		
	5/12/19	+44	84	48.5		6/ 9/19	
						6/30/19	
						7/28/19	
						9/ 2/19	
						9/22/19	
	10/14/19	+31	106	47		10/14/19	
						11/24/19	
	12/21/19	+30	84	47		12/22/19	12/21/19, slightly thyrotoxic, but improving
	3/ 1/20	+28	88	48		3/ 1/20	
						3/22/20	
						4/12/20	
	5/11/20	+29	90	47.5		5/11/20	6/23/23, subjectively well for two years; working for 1 year; slight recurrence of symptoms for 3 months; improved, but not well
						8/11/20	
	1/18/21	+25	96	48 5			
	6/23/23	+28	80	49.5			

TABLE 1.—*Data on Cases in Which Roentgen-Ray Treatment Was Given Following Ligation of the Superior Thyroid Arteries.—(Continued)*

Case (Lab. No.), Age; Duration of Disease	Date	Metabolism	Pulse	Weight, Kg.	Operation	Roentgen Ray Treatment	Remarks
407, Mr. W. C. W., aged 22; 4 months						3/ 3/19	
						3/10/19	
						3/24/19	
						5/ 5/19	
					5/16/19, ligation right superior artery		
					5/19/19, ligation left superior artery	6/ 6/19	
						6/30/19	
						7/11/19	
						10/ 6/19	
	11/16/19	+40	92	56.5		12/15/19	
	1/ 5/20	+44	98	57.5		1/ 5/20	Marked subjective improvement
						1/26/20	
						4/ 6/20	
	4/21/20	+49	92	58.5			
	7/20/20	+16	80	59.5			Feels well; working for one year
500, Mr. D. F., aged 31; 3½ months	3/27/20	+65	110	56.5			
	4/ 3/20	+69	112	47.5		4/ 5/20	
	4/13/20	+61	112	47.4		4/27/20	
	4/28/20	+59	120	50.0	4/28/20, ligation right superior artery		
					5/10/20, ligation left superior artery		
	5/27/20	+65	130	47.5			
	6/10/20	+41	120	49.4		6/14/20	
	6/29/20	+44	108	52.5		7/ 7/20	
						7/28/20	
						8/18/20	
	9/23/20	+45	112	62			Considerable gain in weight; religation of pulsating right superior artery advised
					10/5/20, religation right superior artery		
	1/11/21	+15	80	64			
	6/13/21	+ 3	68	62			
	11/ 4/21	+ 1	66	68			Clinically cured
1964, Mrs. J. M. B., aged 42; 2 years	4/28/23	+86	125	56			
	5/ 2/23	+63	100		5/8/23, ligation right superior artery		
					5/12/23, ligation left superior artery		
	5/16/23	+49	80	54			
	6/13/23	+69	109	59			
	7/ 6/23	+72	106	62		7/ 6/23	
	7/25/23	+57	102	63.5		7/25/23	Lugol's solution, 15 minims daily from 7/25/23 to 10/10/23
	8/15/23	+44	90	64		8/15/23	
	9/ 5/23	+25	78	67		9/ 5/23	
	10/ 4/23	− 7	53	71			Clinically cured

HEMITHYROIDECTOMY AND ROENTGEN RAY

Chart 3 illustrates the effect of hemithyroidectomy, either alone or following ligation, in thirteen cases during two and one half months. The benefit is distinctly more marked than that following ligation only. The drop in the metabolism from +44 to +25 is well sustained; the pulse drop to about 90 is more marked, and the rise in weight is more abrupt than in previous figures from cases following ligation. However, in only one of these cases did the operation promise to be immediately

curative. These patients in general remain distinctly thyrotoxic, and the immediate effect of the operation is somewhat disappointing.

Chart 4 shows the effect of hemithyroidectomy in ten cases previously treated by roentgen ray, followed over a period of four and one-half months. While the general result is somewhat similar, the reduction in the metabolism and pulse is less marked than in cases without roentgen-ray treatment (Chart 3). The immediate drop in metabolism and pulse is less well sustained. Whether this is due to the omission of roentgen-ray treatment, or is a variation on account of the small number of cases charted, cannot be said. In any case, while the results following ligation were slightly better in cases in which the roentgen ray was employed, after hemithyroidectomy they are slightly better in cases that did not have it. We can only conclude that the effect of

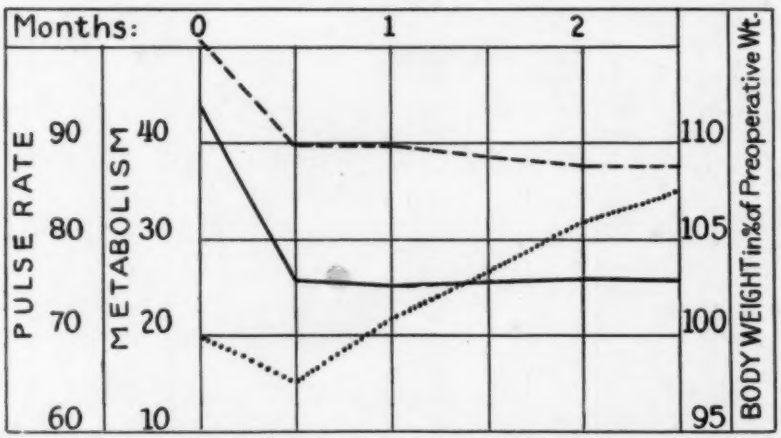

Chart 3.—Effect of hemithyroidectomy without roentgen-ray treatment in thirteen cases, followed two and one half months.

hemithyroidectomy is not increased by previous roentgen-ray treatment.

It should be noted in Chart 4 that there is a tendency to a slow progressive improvement during the last two months. The late effect of performing a hemithyroidectomy is of importance in deciding the proper interval to wait before removing the remaining lobe. Dr. C. A. Porter [5] has recently shown that there is a high percentage of recovery from exophthalmic goiter in cases of hemithyroidectomy followed for some years.

Table 2 shows the results in twenty-two cases of hemithyroidectomy followed over a year, irrespective of whether there had been previous roentgen-ray treatment or not. Since the series is a small one, cases in which an atypical operation, more extensive than hemithyroidectomy was performed, but not complete enough to be called a subtotal

of thyroidectomy, are included, marked with an asterisk. If the roentgen-ray treatment was subsequent to the operation, the case is marked with a dagger. In these cases of known exophthalmic goiter, a metabolism of +15 or over is arbitrarily taken to be above normal limits and to suggest persistent activity of the disease. By giving the date of the last metabolism above normal, and that of the first normal metabolism, a period is delimited during which the metabolism reached normal. With the date of the operation (shown in Column 3), we have as close an approximation to the duration of intoxication in a given case as our observations permit. By reference to the last column, it will be seen that only seven cases still showed clinical evidence of thyrotoxicosis when last observed, as confirmed by an increase in metabolic rate. On

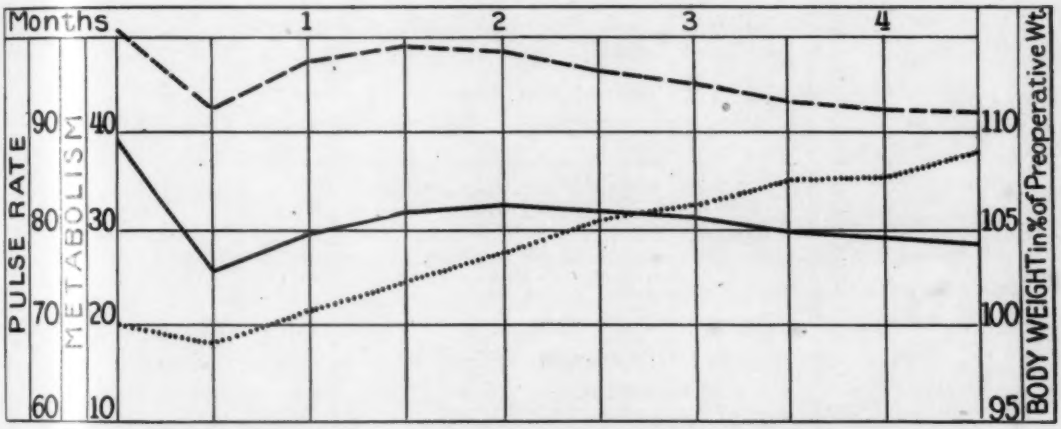

Chart 4.—Effect of hemithyroidectomy after roentgen-ray treatment in ten cases, followed four and one half months.

the other hand, reference to Column 7 reveals that, in eleven cases, there was a persistence of the increased metabolic rate from one to six years. In only four cases (Cases 106, 609, 1008, 1605), as shown in Column 6, do we know that the metabolic rate returned to normal limits within a year.

Therefore, we may say that operations less complete than subtotal thyroidectomy in many instances are followed by activity of the disease for a considerable time. In certain cases, this period is so long that cure seems attributable to the natural course of the disease rather than to treatment. In this connection, it is well to note the spontaneous tendency to recovery shown by Kessel, Lieb and Hyman [6] in a series of cases untreated except by rest. During the persistent toxemia, further

6. Kessel, Leo; Lieb, C. C., and Hyman, H. T.: A Study of Exophthalmic Goiter and the Involuntary Nervous System, J. A. M. A. **79**:1213 (Oct. 7) 1922.

TABLE 2.—*Time of Return of Normal Metabolism Rate Following Hemithyroidectomy*

1	2		3		4		5		6		7	8
Case (Lab. No.)	Preoperative Metabolism	Date of Operation	Last Basal Metabolism Above Normal		First Normal Basal Metabolism		Last Basal Metabolism Observation		Duration of Increased Basal Metabolism Yrs.	Mos.	Maximum Possible Duration of Increased Basal Metabolism	Clinical Result
16*	+30	4/30/15	+31	11/ 8/21	.....		+31	11/ 8/21	6	6	.....	Thyrotoxic
151	+57	3/27/17	+27	11/22/21	.....		+27	11/22/21	4	8	.....	Thyrotoxic
125	+50	1/19/17	+42	11/ 8/20	+ 1	3/23/22	+ 1	3/23/22	3	10	5 yrs. 2 mos.	Cured
106	+50	11/24/16	+24	8/ 5/19	+ 7	12/10/16	+ 6.5	6/23/23	.....		.....	Cured (cardiac)
148	+46	6/28/17	.....		+10	5/11/19	+ 6	11/12/21	.....		1 yr. 10 mos	Cured 2 years 6 months
137†	+56	3/ 2/17	+67	4/ 7/17	+ 4	3/29/19	− 7	6/30/23		1	2 years	Cured 4 years 3 months
227	+63	2/ 2/18	.....		+10	10/18/21	+ 3	10/ 5/23	.....		3 yrs. 8 mos.	Cured 2 years
1134	+65	10/10/21	+17	1/ 7/22	+ 2.5	5/18/23	+ 2	8/15/23		3	1 yr. 4 mos.	Cured 3 months
1167	+61	10/27/21	.....		.....		+18	10/14/22	1		.....	Slightly thyrotoxic
1008	+38	2/ 1/22	+16	4/29/22	+ 1	10/ 9/22	+15	2/17/23		2	8 months	Clinically well
1382	+26	4/12/22	+18	5/17/23	.....		+18	5/17/23	1	1	.....	Slightly thyrotoxic
358†	....	7/ 1/19	+20	6/ 5/22	.....		+15	6/29/23	4		.....	Slightly thyrotoxic (cardiac)
71	+40	9/25/16	+22	4/19/19	+13	12/ 4/19	± 0	12/28/21	2	7	3 yrs. 2 mos.	Cured 2 years
88	+52	11/17/16	+15	11/27/19	+11	12/ 2/19	+ 1	12/28/21	3		.....	Cured 2 years
1061	+26	4/28/22	+15	8/ 2/23	.....		+15	8/ 2/23	1	3	.....	Slightly thyrotoxic
1005	+40	8/26/22	.....		+ 9	9/ 2/22	− 7	7/31/23	.....		1 week	Cured 11 months
655	+34	6/29/20	+20	10/25/20	−12.5	7/15/22	−12.5	7/15/22		4	2 years	Cured
609	+56	10/29/20	+21	1/20/21	± 0	5/20/21	− 7	5/12/22		3	4 months	Cured 1 year, rheumatic heart disease
597*†	+54	5/22/20	+24	9/20/20	+12	9/ 5/21	− 0.5	9/25/22		4	1 yr. 3 mos.	Cured 1 year; dyspnea
121*	+58	4/16/17	+15	4/29/17	+11	4/10/19	− 2.5	11/ 3/21	2 weeks		2 years	Cured 2 years 7 months
586*	+49	6/ 9/20	+21	9/16/21	+21	9/16/21	+21	9/16/21	1	2	.....	Slightly thyrotoxic
99†	+42	11/13/16	+25	3/27/19	+12	11/20/19	+ 9	6/14/23	2	4	3 years	Cured 3 years 7 months
Average...	+47.2	.....	.....		.....		+ 6.9					

* Atypical operation.
† Roentgen-ray treatment after operation.

organic damage is undoubtedly undergone. In three instances not included in the table, this damage led to death or cardiac decompensation within a few months of the operation. While a few cases do show a prompt return of metabolism to within normal limits, this is not the rule. The general surgical opinion that hemithyroidectomy is an inadequate form of treatment for exophthalmic goiter is borne out by these cases.

The fact that late improvement takes place in a certain proportion of cases after hemithyroidectomy makes the time at which a second thyroidectomy should be advised a matter for discussion. As has been shown, the degree of improvement within a few months is somewhat disappointing. However, it is sufficient to make the second partial thyroidectomy a relatively safe procedure. Should this operation be advised as soon as the patient has completely recovered from the previous thyroidectomy, say in two or three months, or should it be delayed for a year or more, in order to see the degree of permanent benefit obtained? We should feel that unless the degree of improvement at the end of two or three months is sufficient to make cure probable, a second thyroidectomy should be performed at about this time.

By this procedure, the duration of the toxemia is lessened, a matter of importance in all cases, and particularly so in those showing evidence of organic damage. The cases of slight persistent toxemia, insufficient to indicate further operative treatment, will be lessened in number. Further, it seems probable that the number of late recurrences of symptoms will be diminished. Finally, a patient may be willing to undergo operation at the end of three months as a part of a definite operative program, who would refuse it at the end of a year if the degree of improvement were sufficient to make life tolerable. On the other hand, the further removal of thyroid tissue does not seem likely to increase to any appreciable extent the danger of myxedema. While waiting a considerable time to see the late results following hemithyroidectomy would seem justifiable in early cases without organic damage, we believe that, on the whole, the best interests of the patient are served when a subtotal thyroidectomy is completed as soon as possible.

In contrast to the results of hemithyroidectomy, Chart 5 shows the effect of the completion of the operation of subtotal thyroidectomy, whether a primary procedure, or secondary to ligation, to hemithyroidectomy, or to both. The starting point of the curves is the last metabolism determination before the final operation. The metabolism shows a drop to +10, as contrasted with +25 or +30, following hemithyroidectomy, and the pulse a drop to 80 instead of to 90 or 100. The weight increase is also more rapid. The actual rate of return of metabolism to within normal limits is quicker than is shown here, as

determined by Segall and Means,[7] through repeated observations at short intervals after operation. Chart 5 only approximates the true rate of the fall of the metabolism. It gives evidence, however, during a period of four months, as to the effect of the operation on the general condition, as shown by the weight.

The chart confirms, we believe, by a comparison with the previous ones, the general opinion that subtotal thyroidectomy is the desired result to be obtained by surgery. How effective this operation will be will depend on how accurately the surgeon estimates the amount of thyroid tissue which should be removed in a given case, and how great is the organic damage resulting from the disease. In cases in which the

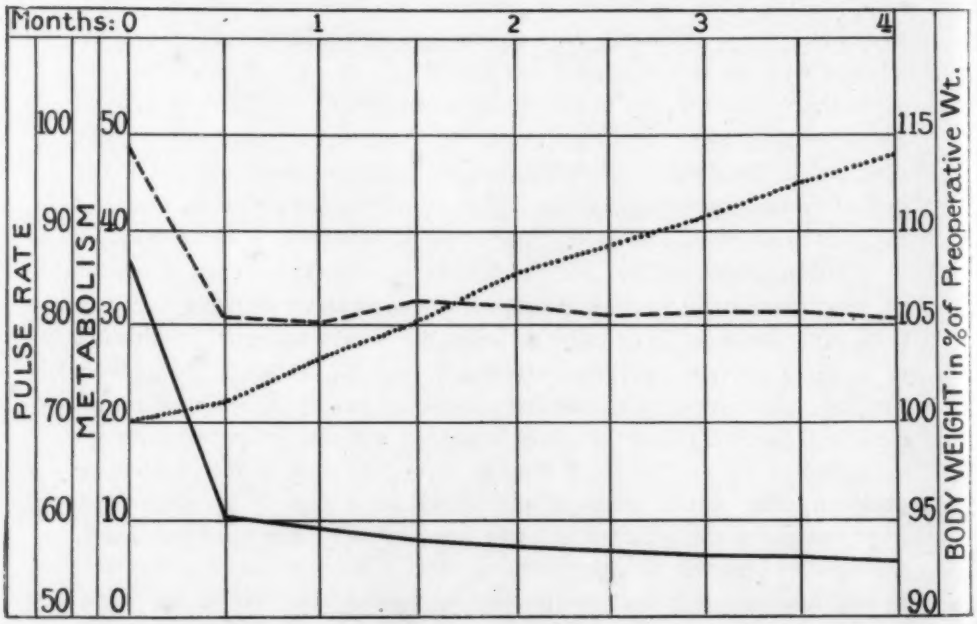

Chart 5.—Effect of the final operation completing subtotal thyroidectomy in twenty cases, followed four months.

risk of an immediate subtotal thyroidectomy is too great, there may be occasionally a choice as to how a removal of the thyroid of this extent is to be secured. Thus, a subtotal thyroidectomy may be performed after ligation of the superior thyroid arteries, or a removal of the gland of the same extent may be obtained by one hemithyroidectomy, followed after an interval of time by a second.

We have already shown in Figures 3 and 4 that the degree of benefit obtained within a few months after hemithyroidectomy is somewhat

7. Segall, H. N., and Means, J. H.: Immediate Effect of Subtotal Thyroidectomy in Toxic Goiter, Arch. Surg. **8**:176 (Jan.) 1924.

disappointing and also that its late results are uncertain. There are other considerations which make hemithyroidectomy an undesirable step on the way to a subtotal thyroidectomy. Patients who undergo ligation of the superior thyroid arteries are surprised by the small amount of discomfort from this operation and are given confidence in undergoing thyroidectomy. On the other hand, patients who have had hemithyroidectomy are considerably disturbed by the operation, and face a second thyroidectomy with some apprehension. This may lead to a refusal of further surgery, particularly if the benefit obtained is considerable.

From the surgeon's point of view, although well tolerated, the operation itself is likely to be somewhat difficult from adhesions and vascularity, even if the muscles over the remaining lobe have not been previously divided. We believe that hemithyroidectomy should be an operation of necessity, to which we are forced to limit ourselves by the patient's condition or his reaction to operation, and not an operation of choice; and that a double superior ligation, followed by a subtotal thyroidectomy, is the preferable procedure, even in patients who seem able to undergo an immediate removal of one lobe of the gland.

EFFECT OF ROENTGEN RAY ON SUBSEQUENT SUBTOTAL THYROIDECTOMY

Tables 3 and 4 show the later results of subtotal thyroidectomy in cases with and without previous roentgen-ray treatment. The tables are intended to show the patient's condition, both as evidenced clinically, and through observations of metabolism, pulse and weight when last seen. The preoperative metabolism is that taken just before the final operation, which completed a subtotal thyroidectomy, and not that taken before the first partial operation preliminary to that procedure. Likewise, the gain in weight is that due to the final operation only, and not the total gain in weight due to all operations on a given patient. Looking at Tables 3 and 4 together, it will be seen that, of twenty-six patients, there are five in whom persistent activity of the disease as shown by the metabolic rate comes into question. In Table 3, Case 524, the patient had a definite recurrence, and has since had excision of more thyroid tissue. In Case 768, the patient was recovering from tonsillitis, but was probably thyrotoxic. In Cases 779 and 1551, Table 3, and Case 389, Table 4, with a metabolic rate of +15 and +18 and +15, respectively, the patient showed no clinical evidence of active exophthalmic goiter. These results are somewhat better than those in Table 2, in which, of twenty-two patients, seven showed evidence of thyrotoxicosis.

Six patients had symptoms probably due more to damage caused by the exophthalmic goiter than to any persistent activity of the disease.

TABLE 3.—*Results of Subtotal Thyroidectomy Without Roentgen-Ray Treatment.*

Case (Lab. No.)	Preoperative Basal Metabolism	Final Operation Date	Last Observation				Time Observed		Myxedema	Cardiac Disturbance	Clinical Result
			Date	Basal Metabolism	Pulse	Weight in Percentage of Preoperative Weight	Years	Months			
223	+54	12/12/17	4/ 2/23	−11	50	136	5	4	0	0	Cured
200	+40	2/13/19	8/ 2/23	−17	68	127	4	5	Clinically no	0	Cured
226	+54	4/ 6/20	10/24/21	+ 1	74	129	1	6	0	0	Cured
310	+45	8/26/19	6/22/23	+ 3	...	114	3	10	0	0	Nervous symptoms; cured
317	+20	9/29/19	10/27/20	− 2	80	123	1	1	0	0	Nervous symptoms; cured
524*	+20	2/ 6/20	11/21/22	+30	115	91.5	2	9	0	0	Recurrence; thyrotoxic
596*	+27	4/29/20	10/26/21	−17	81	136	1	6	Clinically no	0	Cured
768	+54	11/20/20	8/17/23	+28.5	98	103	2	9	0	0	Thyrotoxic (?); tonsillitis
779	+65	11/26/20	7/25/23	+15	76	136	2	8	0	Cardiac	Cured
868*	+53	1/21/21	5/16/22	+ 1	64	141	1	4	0	0	Cured
1074	+29	11/ 2/21	12/ 2/21	−14	72	150	1	1	Clinically no	0	Cured
1120	+27	11/21/21	1/31/23	− 6	85	138	1	2	0	0	Cured
1146	+30	12/ 3/21	11/24/22	− 6.5	75	136	...	11	0	0	Cured
1265	+27	4/24/22	10/24/23	− 1	64	96	1	6	0	0	Cured; organic disease (?)
1551	+37.5	9/20/22	10/13/23	+18	98	137.5	1	1	0	0	Clinically well
Average....	+38.8	.....	.....	+ 1.5	78.6	126.3	2	2			

* Immediate subtotal thyroidectomy.

TABLE 4.—*Results of Subtotal Thyroidectomy After Roentgen-Ray Treatment*

Case (Lab. No.)	Preoperative Basal Metabolism	Final Operation Date	Last Observation				Time Observed		Myxedema	Cardiac Disturbance	Clinical Result
			Date	Basal Metabolism	Pulse	Weight in Percentage of Preoperative Weight	Years	Months			
389	+39	2/ 9/20	12/20/21	+15	92	150	1	10	0	0	Cured
431*	+34	3/29/20	11/21/21	+ 3	65	132	1	7	0	0	Cured
329	+45	6/16/20	8/22/23	+ 8	80	136	3	2	0	0	Cured
328	+35	2/ 9/21	12/18/22	— 4	90	124	1	10	0	Pain, dyspnea	Cured
762	+31	2/16/22	8/10/23	+ 8	77	116	1	6	0	Palpitation, dyspnea	Cured
621	+40	4/14/21	1/10/23	+ 3	63	109	1	9	0	0	Cured
817	+35	6/24/22	1/ 3/23	— 6	58	127	...	5	0	0	Cured
143	+28	6/30/17	4/ 9/19	—11	64	119	1	9	0	0	Cured
803*	+37	3/26/23	10/29/23	— 7.5	71	108	...	7	0	0	Cured
1109	+84	4/29/22	10/ 5/23	—10	60	111	1	6	0	0	Cured
1610	+19	2/15/23	10/ 5/23	—11	68	107	...	8	0	0	Cured
Average....	+38.8	.....	.....	— 1.1	71.6	121.7	1	6			

* Immediate subtotal thyroidectomy.

In Table 3, Case 779, the patient showed evidence of cardiac damage. In Cases 310 and 317, the patients had obscure nervous symptoms without discoverable basis, and in Case 1265, the patient had symptoms suggesting some organic disease, the nature of which could not at the time be determined. In Table 4, Cases 328 and 762, the patients complained of precordial pain, dyspnea and palpitation, without objective evidence of cardiac disease. The occurrence of such cases is an argument for as rapid and complete relief from exophthalmic goiter as circumstances permit.

The average metabolism in Tables 3 and 4 at the last observation was +0.4, as compared with +6.9 in Table 2. We have already shown that the immediate benefit from subtotal thyroidectomy is more marked than that from hemithyroidectomy. These cases also suggest that the late result after subtotal thyroidectomy is more satisfactory.

The mean result in fifteen cases in Table 3 is, at an average time of two years and four months, a metabolism of +1.5, a pulse of 78.6 and a gain of 26.3 per cent in weight. Eleven cases in Table 4, in which roentgen-ray treatment was given, show, at an average time of one year and six months, a metabolism of —1.1, a pulse of 71.6 and a gain in weight of 21.7 per cent.

In regard to the tendency to myxedema, the average metabolism in Tables 3 and 4 is very similar. The inclusion in Table 3 of Cases 524 and 768, with a metabolism of +30 and +28.5, tends to bring up the general average. Three cases in this group, Cases 200, 596 and 1074, showed a metabolism of —17, —17 and —14. None of these cases, however, showed clinical evidence of myxedema. The cases in which roentgen-ray treatment was given, with a low metabolism of —11, show, if anything, an advantage in this respect.

We may conclude from Tables 3 and 4 that the results of subtotal thyroidectomy are very similar in the cases in which roentgen-ray treatment was given, and those in which it was not given. We have no evidence that cases in which roentgen-ray treatment was given show an increased tendency to myxedema after subtotal thyroidectomy.

The effect of subtotal thyroidectomy is distinctly more marked in reducing metabolism than is that of hemithyroidectomy, but we know, of the cases of exophthalmic goiter treated in this clinic, none in which clinical myxedema has been produced by this operation.

The data presented in this paper have no bearing on the general effectiveness of roentgen-ray treatment, or on its value as a preoperative measure in reducing operative risk. For these points, the reader is referred to the paper by Holmes and Means.[2] With regard to roentgen-ray treatment, conclusions may be drawn from the evidence here presented only as to the extent that previous roentgen-ray treatment influences surgery, and, in lesser degree, as to the extent that previous

operation influences roentgen-ray treatment. The following statements are suggested by the cases at hand:

1. The patient's general condition following ligation of the superior thyroid arteries, rather than the metabolic rate, should be the guide to the time of further operation.

2. Ligation of the superior thyroid arteries appears to be slightly more effective in patients having previously had roentgen-ray treatment.

3. We have no evidence as yet that the effectiveness of roentgen-ray treatment is increased by previous ligation of the superior thyroid arteries.

4. The degree of benefit received from hemithyroidectomy is not increased by previous roentgen-ray treatment.

5. Hemithyroidectomy, although occasionally curative, is not a desirable step in the surgical treatment of exophthalmic goiter. It should be followed as a rule by completion of the operation of subtotal thyroidectomy within a few months.

6. We have no reason to believe that myxedema is more likely to occur following subtotal thyroidectomy in patients who have undergone roentgen-ray treatment than in those who have not.

7. The effect produced by surgery in the treatment of exophthalmic goiter appears little modified by previous roentgen-ray treatment.

CONGENITAL HYDRONEPHROSIS *

A REVIEW OF THE LITERATURE WITH A REPORT OF TWO CASES

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Notwithstanding the extensive study of hydronephrosis in recent years, relatively little has appeared in American and English literature on the congenital type. The condition is not common. In 15,800 admissions to the Robert W. Long Hospital, there were only two cases.

Most of the work on hydronephrosis has been related to the early cases of adults, cases which could be detected in their incipiency by modern urologic examination and which afforded the hope of restoring ureteral function and salvaging the kidney. More study of the less hopeful congenital cases may be profitable, because their etiology is not obscured by the scars of many battles with infection, traumatism and indiscretion which individuals of many years of medical history present.

DEFINITION OF CONGENITAL HYDRONEPHROSIS

In 1885, Morris [1] drew a distinction between congenital hydronephrosis and hydronephrosis of congenital origin. He considered the term "congenital hydronephrosis" applicable only to those cases in which the individual is born "ventricose." This distinction is discarded in this paper because it is of slight utility and is too arbitrarily drawn. It is conceivable and probable that a moderate hydronephrosis may exist at birth undetected and, developing slowly, give no evidence of itself until the fourth or fifth year of life. Our definition of congenital hydronephrosis is a dilatation of the renal pelvis with fluid, occurring early in life, and without a demonstrable or probable cause arising postnatally.

FUNDAMENTAL CONCEPTION OF HYDRONEPHROSIS

The first-hand and most natural explanation of any hydronephrosis is that the distention of the renal pelvis is due to a partial or complete obstruction of the ureter. A common-sense interpretation of the pathologic findings in many cases would substantiate this view.

This simple conception is not universally recognized. Throughout the literature and in all the textbooks appears the statement that dilatation of the renal pelvis does not follow sudden, complete obstruction of the ureter, but that primary atrophy of the kidney invariably occurs.

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* From the Department of Surgery, Indiana University School of Medicine. The cases were treated in the operative clinic of the University Hospital by Dr. Willis D. Gatch, whose assistance in preparing this report is herewith acknowledged.

1. Douglass: Surgical Diseases of the Abdomen, 1909, p. 517.

EXPERIMENTAL URETERAL OBSTRUCTION

The effect of ureteral obstruction brought about experimentally has been tested many times and the results of the experiments are widely divergent. Lindeman [2] produced "exclusion" of the ureter in six dogs, and found that in three atrophy of the kidney occurred and in three hydronephrosis resulted. He concluded that the varying effects of ureteral obstruction were determined by differences in the compensatory anastomotic circulation established through the vessels of the renal capsule, and that the development of competent anastomoses was essential for the continuance of "secretion."

Sollmann, Williams and Briggs [3] found, in a similar series of experiments with four dogs, that hydronephrosis occurred in every case, but that the fluid in the renal pelvis was very poor in urinary constituents and was more properly described as a transudate than as urine.

Rousahoff [4] states that Guyon, Robinson and Bradford show conclusively that complete obstruction of the ureter causes atrophy and only slight distention of the renal pelvis. On the other hand, Corbett, Keith and Snowden [5] and Scott [6] all report that primary atrophy seldom occurs after complete ureteral obstruction, but that hydronephrosis almost invariably follows. Scott employed fifty dogs, and of thirty used for complete obstruction with double silk-worm gut ligatures, only one showed primary atrophy at necropsy. All of the others showed typical hydronephrosis. Other dogs were used for observing the effects of partial ureteral blocking, and by studying comparable cases from the two series, Scott concluded that the degree of hydronephrosis is directly proportional to the amount of obstruction. A significant side observation was that the kidney became infected in every case.

Whether there is any relationship between the occurrence of infection and the development of hydronephrosis is not stated in any reports available to the writers. This problem might supply the point of attack in further experimental studies.

In 1912, Barney [7] reported a series of experiments indicating that sudden, complete closure of the ureter causes hydronephrosis. In 1917, he reported that the development of hydronephrosis with an occluded ureter is coincident with the formation of venous anastomoses between the capsule and adjacent venous channels. In only one of thirty-three experiments did hydronephrosis fail to ensue, and in that case the

2. Lindeman: Ztschr. f. klin. Med. **34**:299, 1898; cited by Bottomley.
3. Sollman, Williams, and Briggs: J. Exper. Med. **9**:71, 1907.
4. Rousahoff: Keen's Surgery **4**:219, 1919.
5. Corbett, Keith and Snowden: Am. J. M. Sc. **144**:568, 1912.
6. Scott: Surg., Gynec. & Obst. **15**:396, 1912; J. Indiana M. A. **6**:339, 1913.
7. Barney, J. D.: Ann. Surg. **65**:597 (May) 1917.

venous supply to the capsule was found to be very poor. Scott surrounded the kidney with a sac at the time of ligation to prevent the formation of anastomoses and still found that hydronephrosis and not primary atrophy developed.

Believing that the conflict in the experimental results heretofore published is not susceptible of explanation on any known grounds, the author proposes to conduct a series of experiments in which the influence of infection, disturbance of blood supply and method of obstruction will be carefully controlled and evaluated.

NONOBSTRUCTIVE HYDRONEPHROSIS

Bland-Sutton [8] states that one of the remarkable facts in his study of hydronephrosis is that, in many of the larger cysts, no obstruction could be found. D'Astros [9] reported a case of unilateral, congenital hydronephrosis in which no abnormality of the ureter could be found aside from its insertion into the middle of the lower pole of the kidney. The tube could easily be catheterized into the renal pelvis. The distal end was not available for examination, but the absence of dilatation of the proximal end made it extremely unlikely that any stricture was present lower down.

Cases of bilateral hydronephrosis with bladder retention and without any discoverable narrowing of the urinary passages are more plentiful. Buerger [10] reported such a case, in 1914, and reviewed the literature. In some of these cases, concomitant signs of a spinal lesion are present and clearly stamp them as paralytic. A certain residual group present no such signs, and if a nerve lesion exists, its phenomena must be localized in the lowest reflex centers of the bladder. Brueger was forced to the conclusion in his case that the renal and ureteral distention could not be explained by back pressure alone and that there must have been a primary congenital enlargement.

If the idea of motor paresis as a cause of hydronephrosis had remained restricted to the cases with bladder retention and bilateral hydro-ureter, it would deserve only passing mention in this paper. But muscular impotence of the renal pelvis and ureter has been invoked to account for cases of typical unilateral hydronephrosis in which a ureteral obstruction could not be demonstrated. Certainly, a motor insufficiency of only the renal pelvis and ureter of one side would be an extremely difficult condition to account for. No case is known to have been reported in which the paresis was actually demonstrated, and hydronephrosis has never, to the knowledge of the writer, been reported as an effect of experimental division of the nerve supply of the kidney.

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8. Bland-Sutton: Cited by Douglass (Footnote 1).
9. D'Astros, M. L.: Bull. Soc. de pédiat. **15**:435, 1913.
10. Buerger, Leo: Internat. Clin. **4**:243, 1914.

Herrick [11] considers that renal distention is not conceivable as a result of only muscular impotence and that some degree of obstruction is necessary. Yet he admits motor insufficiency as "one of the factors" in the development of hydronephrosis: "Motor insufficiency working against an obstruction causes ectasis." It would seem altogether logical to ascribe the retention to the obstruction and not to the musculature, which we have no reason to assume is other than normal, although unequal to the task of overcoming abnormally high resistance.

Without more definite proof than has been advanced, motor insufficiency may be dismissed as a cause of hydronephrosis. With closer study of the mechanical relations of the ureters and kidneys, the group of mysterious unexplained cases will no doubt grow relatively smaller, and the view of Geraghty,[12] who says, "It seems fair to assume that every (typical) hydronephrosis is the direct result of some mechanical obstruction to the outflow of urine from the renal pelvis," will be sustained.

URETERAL OBSTRUCTION

Congenital absence of the ureter may be dismissed as a possible cause of hydronephrosis. Without going deeply into the embryology of the urinary system, it will be sufficient to recall that the renal pelvis and ureter arise in one anlage—a bud springing from the dorsal wall of the Wolffian duct near its junction with the cloaca. A hydronephrosis without a renal pelvis is inconceivable, and a renal pelvis without a ureter is a developmental impossibility. Yet, absence of the ureter is mentioned in textbooks and papers as a cause of hydronephrosis.

Abnormal renal mobility finds a place in most textbook lists of causes of hydronephrosis, although it is seldom stressed in relation to large congenital hydronephrosis. Lajoscade [13] admits mobilization of the kidney as a cause of relative ureteral obstruction. Michailow [14] reported a unique case of hydronephrosis in a 2-year-old boy, in which abnormal mobility seemed to play a part. Herrick believes that renal mobility is a predisposing factor.

Geraghty and Frontz [12] state that, in their series of fourteen cases of primary hydronephrosis, in not a single instance could renal mobility have been the sole cause. The same writers say: "It is not conceivable that the pathologic changes of hydronephrosis can be brought about

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11. Herrick, F. C.: J. Urol. **5**:1 (Jan.) 1921; Cleveland M. J. **15**:704 (Nov.) 1916.

12. Geraghty, J. T., and Frontz, W. A.: J. Urol. **2**:161 (June) 1918.

13. Lajoscade, Emile: Am. J. Urology **9**:373, 1913.

14. Michailow, N. A.: Relation of Anomalous Renal Blood Vessels to Hydronephrosis, Ztschr. f. Urol. **7**:564, 1913.

by intermittent distention of the renal pelvis;" such as might result from excessive renal mobility; and they further point out that in a long series of cases in which operation was performed for mobile kidney, hydronephrosis was never observed; and that the statistics of hydronephrosis do not parallel those of movable kidney.

Ectopic kidney and horseshoe kidney have been reported as associated with congenital hydronephrosis, and the renal retention has been ascribed to the abnormal course the ureter assumes in those conditions.

The presence of anomalies of the blood vessels has been emphasized by Mayo[15] as a common cause of hydronephrosis. Geraghty and Frontz advance evidence and arguments casting considerable doubt on the effect of vascular abnormalities. It has been pointed out that small fibrous bands may be mistaken for blood vessels; that there are cases of hydronephrosis uncured by division of the anomalous vessels which are apparently responsible for the condition; that improvement after such operations may be due to postoperative scar formation with fixation of a movable kidney, and that some sketches submitted in proof of the effect of anomalies of blood vessels have shown the ureteral dilatation beginning at a level higher than the crossing of the vessel.

Obliquity of ureteral "insertion" into the renal pelvis is considered by some writers (Piersol[16]) a cause, by others an effect, of hydronephrosis. It is certainly true that a kidney with a developing pelvic retention turns on its pedicle because of increased weight. The obliquity of the ureter with respect to the renal pelvis increases until the ureter becomes adherent to the sac and appears to run for a distance in its wall, but in reality between the renal pelvis and the overlying adherent peritoneum. After such a condition has developed, it is impossible to evaluate accurately the etiologic importance of the original relation of the ureter to the kidney.

As regards accessory ureters, of fifty-six cases of ureteral stricture collected by Bottomley,[17] eleven were associated with a supernumerary ureter. But a multiplicity of ureters could not per se cause obstructive phenomena. As much as can be drawn from this association is that ureteral stricture is prone to occur when there are other evidences of developmental imperfection.

Persistence of fetal valves, folds, kinks and twists of the ureter has, as a last resort, been seized on as the cause of ureteral obstruction in those cases of most obscure etitology. A good account of the irregulari-

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15. Mayo, W. J.: J. A. M. A. **52**:1383 (May 1) 1909; Collected Papers Mayo Clinic, 1905-1909.

16. Piersol, G. A.: Human Anatomy, Philadelphia, J. B. Lippincott Company, 1907.

17. Bottomley: Ann. Surg. **52**:597, 1910.

ties of the fetal ureter is given by Posner,[18] whose point of view is that the study of apparently normal embryos and new-born infants is likely to be more fruitful in elucidating hydronephrosis than the observation of old cases wherein the congenital anlagen are overlaid by gross secondary changes. Posner reviews the development of our knowledge of the vagaries of the normal ureter; Waldeyer first described its changes of direction, although with those we are concerned only so far as they are associated with constrictions of the lumen. Von Poirier discovered the natural stenosis at the vesical end. Halle showed that stenosis occurs in the free part of the tube, and E. Schwalbe established the location of these straits, in an exhaustive study. He located the uppermost narrowing near the renal hilum. The middle constriction is at the crossing of the pelvic brim where an angulation occurs. At this level, the right ureter is farther from the midline than the left, crossing the external iliac artery instead of the common iliac as on the left. Between these straits, a dilatation is found, the *Hauptspindel,* more exaggerated on the right. Schwalbe concluded that the upright posture has something to do with these variations in the lumen, since comparative anatomy shows their presence only in man and the anthropoid apes. Wetzel, in later studies, supported these conclusions and added that, in the new-born, there is a downward displacement of the viscera which contributes to the angulation of the ureters. Bazy employed injection methods in 100 cadavers of new-born infants and of sixty-three useful specimens found "normal" relations in but fifteen. The other forty-eight showed such abnormalities as stenosis, kinks, torsion and greater or less dilatation of the renal pelvis.

Seitz,[19] Robinson,[20] Hamann [21] and others have shown the existence of these points of narrowing and find that they are remarkably constant. Eisendrath [22] states that valves are found in about 20 per cent. of cadavers of apparently normal children. Seitz found that the embryonic irregularities become more marked toward the end of fetal life. Wolffler [23] observed twenty more or less well marked transverse folds in the mucosa of the ureters of 100 cadavers of new born infants.

English,[24] finding a remarkable correspondence in location of definite strictures and normal narrow zones, considers that these irregularities are generally temporary but that in some cases they persist and

18. Posner, C.: Arch. f. klin. Chir. **106**:381, 1915.
19. Seitz: Cited by Eisendrath: Surg., Gynec. & Obst. **12**:533, 1911.
20. Robinson, Byron: Anat. Anz. **24**:482; cited by Bottomley (Footnote 17).
21. Hamann: J. M. Res. **3**:125, 1902; cited by Bottomley (Footnote 17).
22. Eisendrath: Footnote 19.
23. Wolffler: Cited by Geraghty and Frontz (Footnote 12).
24. Englisch: Cited by Geraghty and Frontz (Footnote 12).

give rise to hydronephrosis. Eisendrath also attributes stricture to persistence of fetal conditions.

Strictures of the ureter so situated or of such a grade as to require explanation on other grounds than mere persistence of fetal irregularities remain as well-demonstrated causes of hydronephrosis. Baudoin [25] traces these strictures to the congenital bends, on the theory that the dilatation proximal to the bends causes chronic irritation leading to fibrous tissue formation, thickening of the ureteral wall, contraction and eventual occlusion. However closely related strictures of the ureter may be to congenital bends, Baudoin's theory is subject to criticism based on many cases of hydro-ureter in which the ureteral wall is greatly attenuated instead of thickened. Secondary infection almost always occurs in hydronephrotic sacs, both in experimental animals and in man, and chronic infection is no doubt the cause of definite fibrosis when it is observed in association with ureteral or pelvic dilatation. Hunner,[26] Bottomley and Geraghty attribute fibrotic thickenings of the ureter, with encroachment on the lumen, to inflammation and not to mechanical irritation.

Lajoscade falls back on anomalous vessels as a cause of ureteral strictures, claiming that the constant pounding of the arterial pulse sets up a ureteritis or periureteris ending in fibrosis and complete occlusion, thus transforming an open into a closed hydronephrosis.

Bottomley [17] collected and abstracted reports of fifty-six cases of congenital stricture of the ureter. In only eight of these was the stricture in the upper one third of the ureter, and then it was generally very near the ureteropelvic junction. In thirty-six cases, the stricture was near the bladder. The author comes to no conclusion regarding the etiology of ureteral stricture in early life.

Von Mutach reported a case which he attributed to arrest of development in a fetal stage. Virchow disagreed with him and assumed that an intra-uterine inflammatory process was responsible. In this connection, there will be recalled Virchow's now repudiated theory of the formation of congenital polycystic kidney by an inflammatory obstruction of the collecting tubules in fetal life. It may also not be amiss to note that congenital polycystic disease of the kidneys has been not infrequently confused, in the older literature, with congenital hydronephrosis.

Geraghty and Frontz,[12] in studying fourteen cases of primary hydronephrosis in the Brady Clinic, found one case of noninflammatory thickening of the "ring muscle" at the ureteropelvic junction and attributed it to a congenital defect. In their series, there was but one ureteral

25. Baudin: Cited by Lajoscade (Footnote 13).
26. Hunner: Cited by Geraghty and Frontz (Footnote 12).

stricture that was free of fibrosis and inflammatory cell infiltration, and this is the only stricture which they consider to have had a congenital origin.

REPORT OF CASES

CASE 1.—*History.*—R. A., boy, aged 8 years, admitted to the Robert W. Long Hospital, June 22, 1920, for treatment of an extreme enlargement of the abdomen, was the third born of four children. In the family history, there were no significant points. The child was born with an unusually large abdomen. The tumor grew in proportion to the boy's general development until a few months prior to admission, when it enlarged more rapidly and became a source of great inconvenience and alarm. After the patient's fifth birthday, the mother had

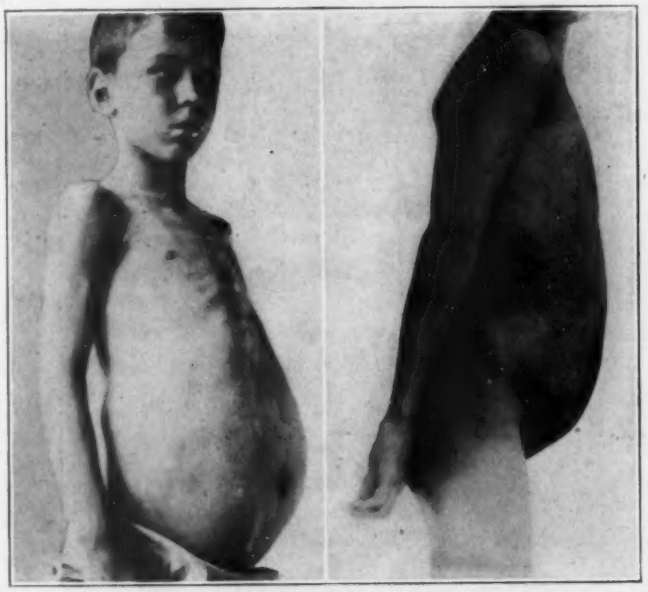

Fig. 1 (Case 1).—Appearance of patient: left: before operation; right: after operation.

observed that blows or falls on the abdomen were the apparent cause of hematuria lasting for days or even weeks.

Physical Examination.—The patient was bright and well nourished. The only significant abnormalities presented were lung resonance extending inferiorly only to the inferior angles of the scapulas posteriorly and only to the fourth rib anteriorly on the right side. On the left side anteriorly, lung resonance merged with stomach tympany. The abdomen was greatly distended and the costal borders were flared. There was no bulging of the flanks, and the abdominal enlargement was most marked anteriorly. The contour of the abdomen was uneven, presenting a number of low, rounded bosses, the largest of which, 12 cm. in diameter, was situated below and to the right of the umbilicus. To the left of the umbilicus was a boss 5 cm. in diameter, and above, another smaller one. The abdomen was dull on percussion with the exception of an

irregular area more or less closely corresponding to the left upper quadrant and extending down somewhat into the left flank. The entire right side of the abdomen gave the thrill of contained fluid to the palpating hand when tapped with the fingers. The urine was perfectly normal. The Wassermann test of the blood was negative. The phenolsulphonephthalein output was 58 per cent. in two hours. Fluoroscopic examination showed the colon pushed up and to the

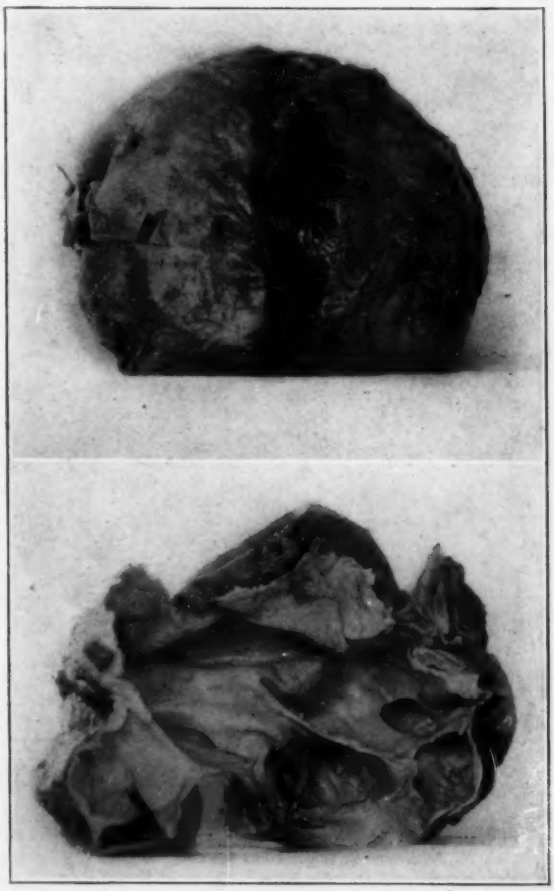

Fig. 2 (Case 1).—Gross specimen of tumor; above: exterior, showing sulci for blood vessels; below: interior, showing compartments.

left; this ruled out megacolon, and indicated that the tumor was apparently retroperitoneal in location. The diagnosis was cystic tumor of the right kidney.

Operation.—Through a midline incision, the abdomen was explored. A thick walled sac of irregular contour, distended by about 1 gallon (4 liters) of fluid, filled almost the entire abdomen. The sac was retroperitoneal and was attached by a pedicle in the situation normally occupied by the right kidney. To expedite removal, the sac was evacuated. A careful search for the ureter was unavailing.

All the abdominal organs were normal except the left kidney which was about twice the normal size. The peritoneum over the sac was incised and stripped back to the pedicle, the vessels of which were divided and ligated. The sac was excised and the abdomen was closed without drainage. The fluid from the sac was clear and straw-colored, and had a specific gravity of 1.004. Mucin was one plus; albumin (heat and acetic acid test), four plus. Unfortunately, the non-protein nitrogen content was not determined.

Postoperative Course.—Convalesence was uneventful until the fifteenth day, when the patient suddenly complained of pain in the left leg. Examination

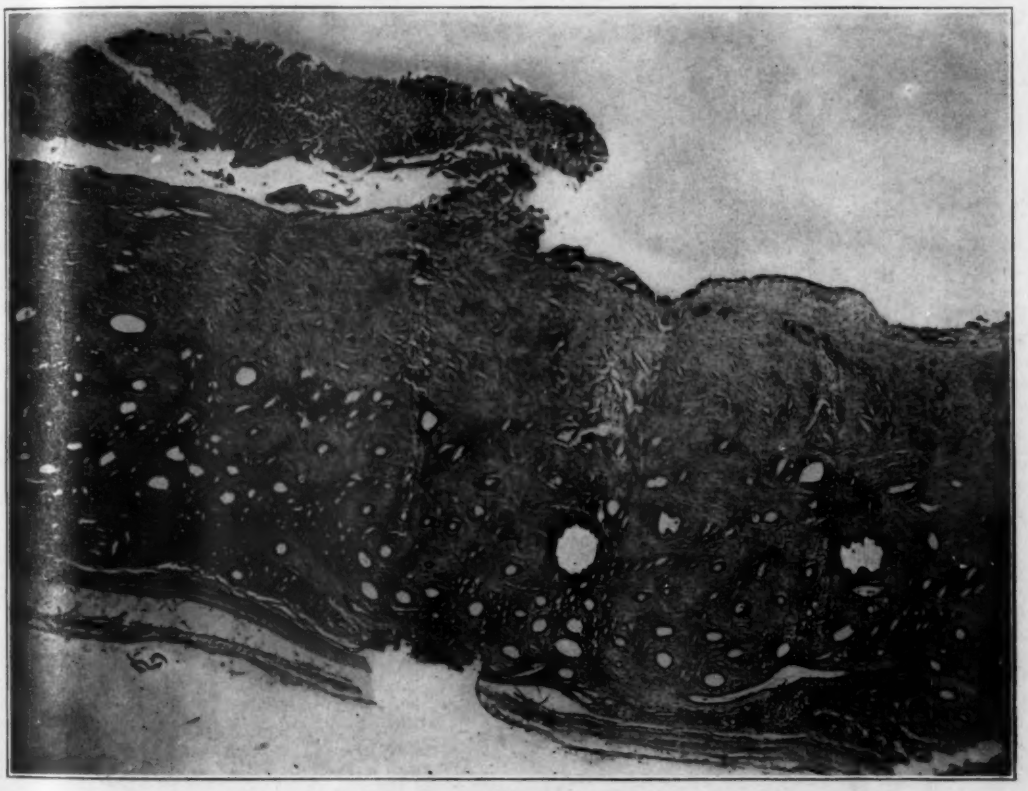

Fig. 3 (Case 1).—Photomicrograph (×200) through cyst wall, showing patch of granulation tissue on inner wall and degenerated renal tubules.

almost immediately afterward disclosed a marked swelling below the knee. In less than fifteen minutes, the entire member was greatly swollen, cold and decidedly cyanotic below the knee. A pulse was perceptible in the dorsalis pedis artery. For the next five days, the temperature ranged from 99 to 102 F. In twenty-three days, the swelling had subsided until the leg was almost normal in size, and the patient was discharged, afebrile and apparently cured. Subsequent letters from the mother convey the information that the boy is quite well and going to school regularly. The postoperative complication of thrombosis in a patient of 8 years old is extremely rare.

Gross Pathology.—The specimen was a cystlike structure approximately 20 cm. in diameter after several weeks in 10 per cent. solution of liquor formaldehydi. Blood vessels ramified over its external surface, traversing shallow sulci, and converging toward a hole 4 cm. in diameter, which represented the point of attachment. The wall was leathery and varied in thickness from 2 to 4 mm. The defect above described opened into a main cavity which communicated with six subloculi formed by narrow, falciform septums which give the interior an arched and groined appearance. The inner surface was white and

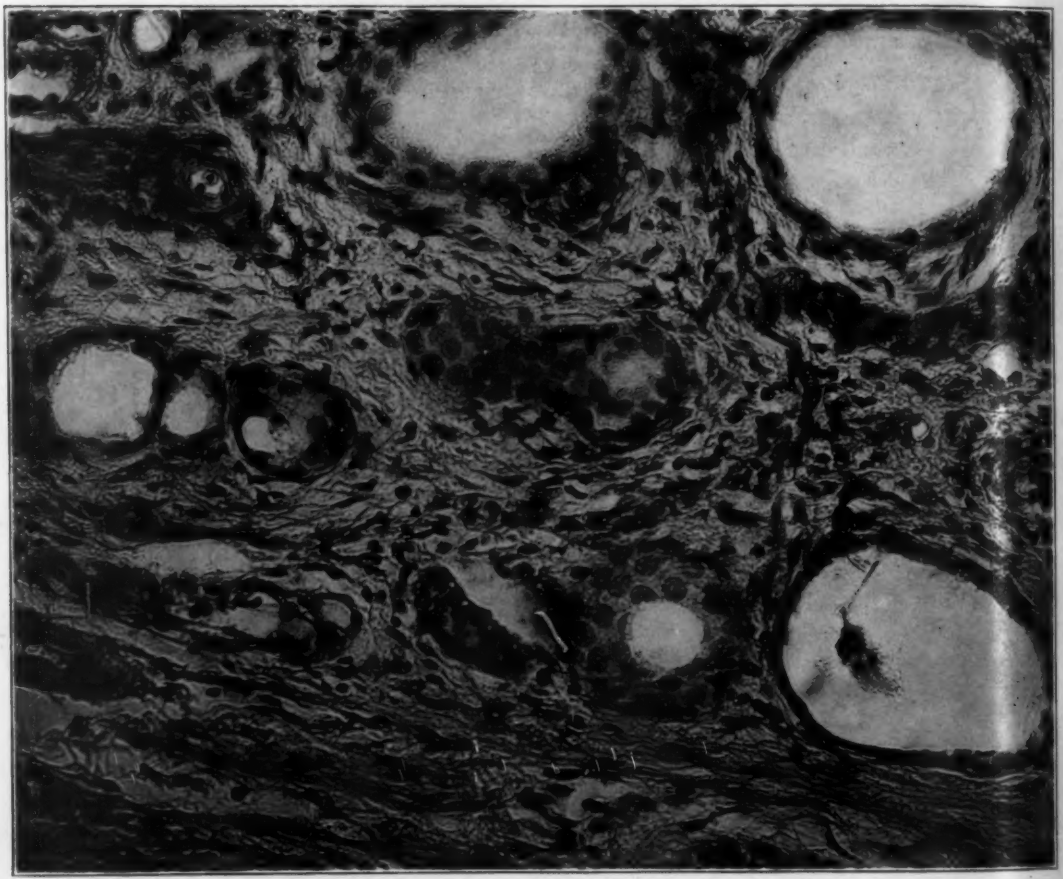

Fig. 4 (Case 1).—Photomicrograph (× 500) showing epithelial hypertrophy in persisting tubules and a stage in the coalescence of adjacent tubules.

glistening, although pitted, and had no covering membrane capable of being stripped. Careful search over the whole exterior and interior failed to reveal any sign of a ureteral orifice or of a ureter.

Microscopic Pathology.—Sections through the wall of the sac showed three rather definite zones. The outer zone was a thickened peritoneal covering. The middle layer consisted of a matrix of edematous fibroblastic tissue studded with tubular structures of various sizes. The larger tubules were lined with

flattened epithelium; whereas the smaller ones had cuboidal epithelium which was here and there heaped up so as to encroach on the lumina. Some of the larger spaces had been formed by coalescence of smaller ones, as shown by numerous adjacent tubules in intermediate stages of fusion. In one part of the wall, the tubules were surrounded by dense mantles of fibrous tissue which merged peripherally with the more richly cellular fibroblastic tissue. The innermost zone was of fibrous tissue uncovered by any discernible epithelium. This layer was edematous and under high power vacuole-like spaces could be seen between the fibers. The surface was broken here and there as though by the eruption of these droplets into the general cavity of the sac. In several places in the smaller loculi, elevated patches of proliferating granulation tissue were found on the inner surface.

COMMENT

The epithelial structures must have represented kidney tubules, yet in no part of the sac was it possible to find evidence of their communicating with the interior. The complete absence of glomeruli may be taken to indicate the degree of retrogressive change in the kidney. Notwithstanding the absence of tissue ordinarily assumed to be responsible for the bulk of renal secretion, the tubules showed unmistakable signs of distention. In the absence of communication with the interior of the sac, this distention must be ascribed to secretory activity on the part of the tubular epithelium.

Even allowing that the tubules communicated with the interior of the sac in some undemonstrated manner, which seems unlikely, we still have to account for several liters of fluid. The amount of functioning epithelium in the tubules must have been entirely unequal to the task of producing such a bulk of fluid as the recent growth of the cyst implies. It may no doubt be safely assumed that in the early stages of the condition the fluid was practically urine, but the recent rapid accretions must have been due to something akin to the ordinary edema-producing mechanism. The tubules may have been distended by back pressure.

The sequence of events in this case was probably as follows: 1. A congenital stenosis of the ureter at or near the uretero-pelvic junction, due to abnormally unequal growth after the formation of the renal pelvis, calices, and tubules. 2. The development during fetal life of an ordinary uronephrosis. 3. The complete occlusion of the ureter and the incorporation of its proximal end in the wall of the renal pelvis (more accurately between the adherent peritoneum and the outer wall of the sac), due to the changing position and rapid growth of the kidney cyst. 4. The complete atrophy of the distal end of the ureter. 5. The gradual degeneration and eventual obliteration of the glomeruli and most of the tubules with some abortive regeneration of tubules and compensatory hypertrophy of their epithelium. 6. Finally, the continued distention of the cyst by an edema-producing mechanism, con-

ceivably due to the initial high osmotic pressure of the primary urinary contents and the changing permeability of the wall as the renal structures underwent retrogression. With moderately yielding walls, distention could continue until the osmotic pressure of the contents of the sac became practically equal to that of blood fluids. It is regretted that a more detailed chemical and physical study of the fluid in the sac was not made.

CASE 2.—*History.*—W. H., aged 4 years, admitted to the Robert W. Long Hospital, Aug. 29, 1920, for treatment of a moderate enlargement of the abdomen, was the seventh child. The family history was negative. At birth, the child was apparently normal, and since birth he had experienced no illnesses. The abdominal tumor was first observed when he was about 1 year old.

Physical Examination.—The patient was well developed and well nourished. The abdomen protruded anteriorly with no bulging of the flanks. On palpation, a definite tumor mass could be made out, extending from the costal borders to the symphysis pubis, and occupying the right side of the abdomen. The left

Fig. 5 (Case 2).—Gross specimen; exterior view showing proximal end of ureter.

border of the tumor extended about 4 cm. beyond the midline. The mass had the consistency of a cyst containing fluid under considerable pressure, affording the characteristic thrill. The left side of the abdomen and a narrow margin below the right costal border were tympanitic. Over the tumor, the abdomen was dull. The urine was normal. The phenolsulphonephthalein output was 58 per cent. in two hours. The diagnosis was cystic tumor of the right kidney.

Operation.—The abdomen was explored through a midline incision. The colon was crowded to the midline by a large retroperitoneal cystic tumor. At the inferior pole of the mass, there was tissue resembling renal cortex. The blood supply resembled that of a normal kidney, and no significant abnormalities could be found. The left kidney was normal on palpation. The cyst was evacuated of about 2 liters of clear amber fluid. The peritoneum over the sac was incised and dissected down to a pedicle which contained a very narrow ureter. The structures of the pedicle were clamped, divided and ligated. Closure was made without drainage.

Postoperative Course.—Recovery was complicated by a partial dehiscence of the abdominal wound with the escape of a quantity of sanguinous pus. (Before

operation, the patient had shown temperature variations from 98 to 100 F.). The child was discharged on the twenty-third day, apparently cured, with the abdominal wound completely healed. Subsequent reports from the parents signify that the child has remained in good health.

Gross Pathology.—The specimen was a cystlike structure about 10 cm. in diameter. The surface was rendered irregular by six definite bosses correspond-

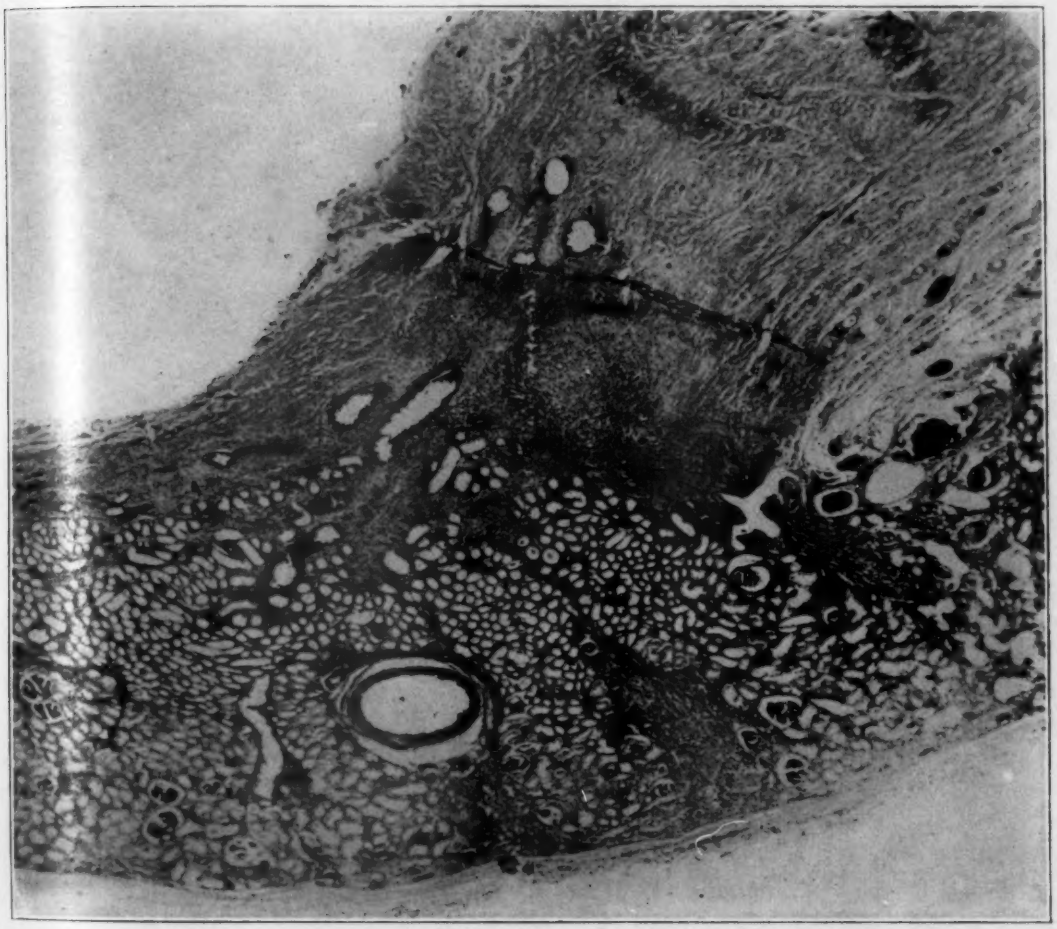

Fig. 6 (Case 2).—Photomicrograph (× 200) of cyst wall showing degenerated renal glomeruli and tubules.

ing to six saccules opening into the main cavity of the structure. On the exterior, a rough area with stumps of blood vessels represented the pedicle. Here, the proximal end of the ureter was found. On opening the sac, the ureteral orifice could be identified by squeezing a drop of water through the ureteral stump. The orifice was minute, without the normal funnel-shaped opening. A brass pin could not be passed through it. Viewed from the exterior, the most proximal half centimeter of the ureter was 1 mm. in outside

diameter. About 1 cm. from the sac, the outside diameter was 2.5 mm. The ureteral stump was not surrounded by any inflammatory deposits and was easily dissected from adjacent structures. The wall of the sac varied in thickness from 0.5 to 1 cm., and, in its outer layers, tissue resembling renal cortex could be seen in thin flakes. The inner surface of the sac was white and glistening but much pitted.

Microscopic Pathology.—Sections through the wall of the sac showed two main zones: an outer layer of degenerated renal cortex covered by a thickened

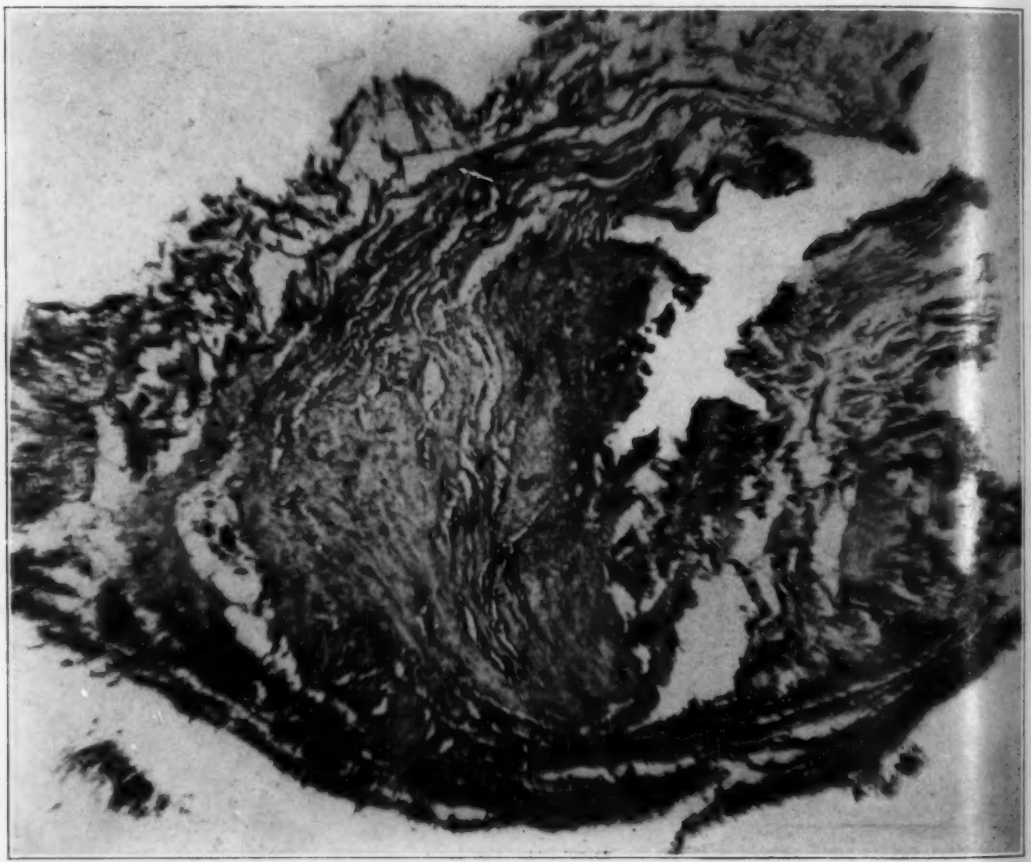

Fig. 7 (Case 2).—Photomicrograph (×200) of ureter at level of greatest constriction.

capsule and peritoneum; and an inner zone of proliferating fibrous tissue, bearing on its internal surface a thin, interrupted degenerated epithelial covering. The glomeruli and tubules of the renal tissue showed various stages of degeneration, and there were numerous areas of round-cell infiltration. In the inner zone were a few dilated tubules, the epithelium of which showed the abortive hypertrophy so often seen in partially occluded and distended ducts. Unfortunately, no section was obtained showing a communication of these tubules with

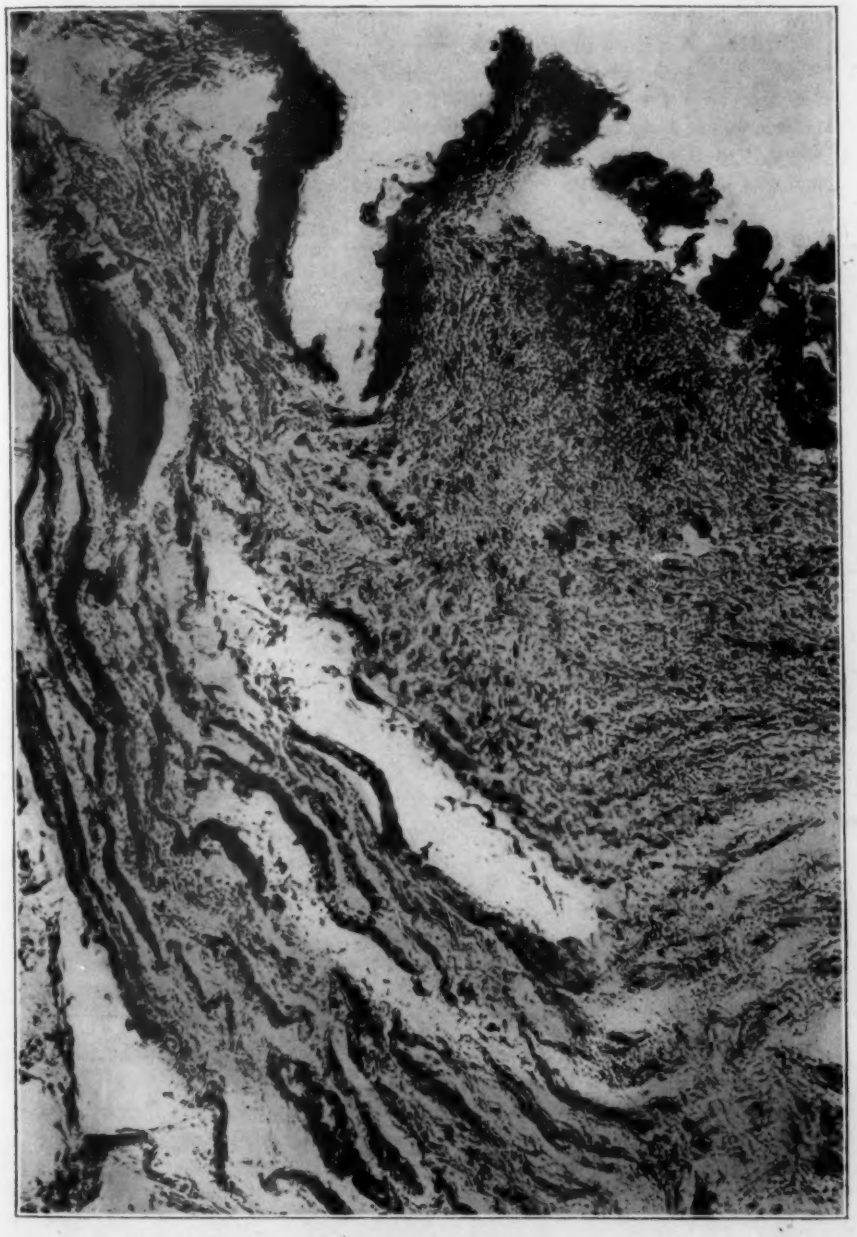

Fig. 8 (Case 2).—Photomicrograph (× 500) of same section through level of constriction. Fibrous tissue thickening of submucosa may be noted.

the inside of the sac, but some of them lay very close to the inner margin; and in some of the sections, depressions lined with pseudostratified epithelium extended from the inner surface of the sac into the fibrous tissue toward the tubules.

The chief interest centered around the ureter. Serial sections from the pelvic orifice to a point well beyond the region of constriction showed a normal structure with the exception of the first 5 mm. This region of constriction showed a patulous lumen throughout, although the inner diameter was only half that of the lumen beyond the constriction. The epithelium in the narrow part was degenerated and partly desquamated. The submucosa was thickened

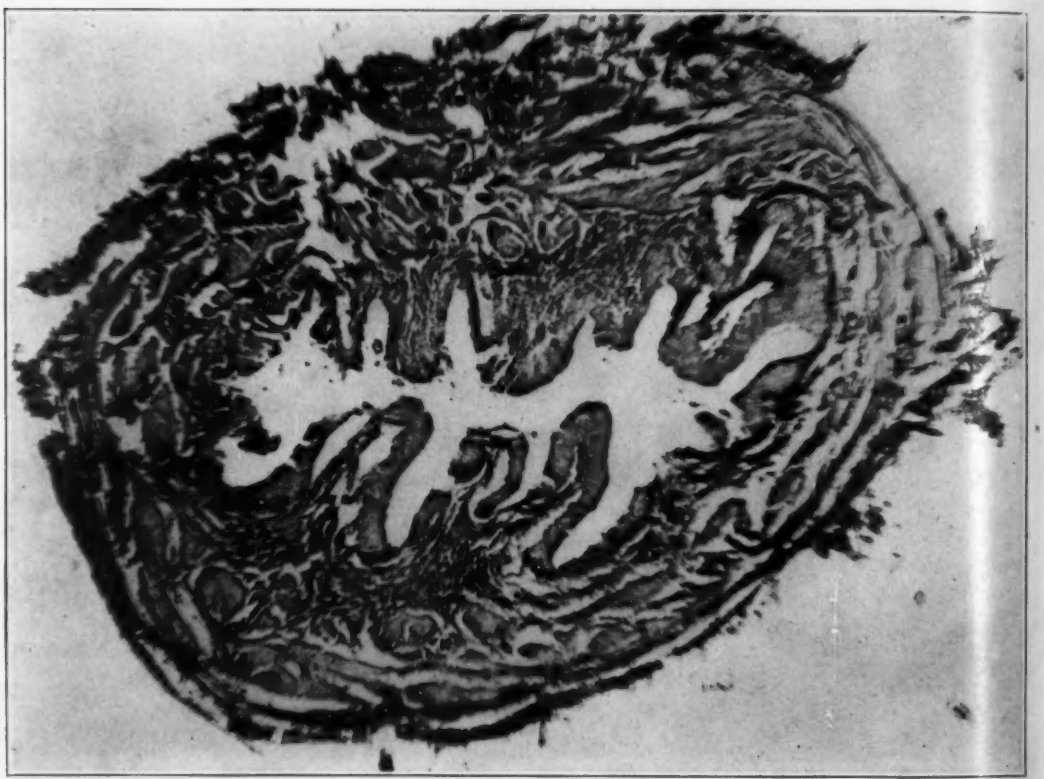

Fig. 9 (Case 2).—Photomicrograph (×200) of ureter below zone of constriction.

and fibrous, and near the muscular coat were several patches of slight perivascular round-cell infiltration. There is no detectable hypertrophy of the "ring muscle."

COMMENT

In spite of the thickened submucosa of the ureter and the slight inflammatory cell infiltration, this ureteral stricture is not regarded as of inflammatory origin. In the gross dissection, there were no signs of periureteral inflammation, no firm adhesions, and no excessive vascularity.

The thickening of the submucosa was at a level of normal stenosis where the longitudinal muscle layer becomes deficient and where the circular layer constitutes the so-called "ring muscle." The focal infiltration of the kidney tissue and the few round cells in the ureteral submucosa could not be construed as signifying any more than a low grade secondary infection of the hydronephrotic kidney. In spite of the statement of Braasch,[27] "congenital stricture (of the ureter) is of such rarity as to be an almost negligible factor" (in producing hydronephrosis), the author considers that the case herewith presented originated with a congenital stenosis near the ureteropelvic junction.

SUMMARY

1. In 15,800 admissions to the Robert W. Long Hospital, there were two cases of congenital hydronephrosis.

2. Congenital hydronephrosis may be defined as a dilatation of the renal pelvis with fluid, occurring early in life, and without a demonstrable or probable cause arising postnatally.

3. Cohnheim's dictum that sudden, complete obstruction of the ureter causes primary atrophy and not hydronephrosis of the corresponding kidney is accepted without question in many textbooks and papers.

4. The published results of ureteral obstruction in experimental animals are in sharp disagreement.

5. Variations in capsular anastomotic blood supply have been suggested as the cause of variable results of ureteral obstruction. Experimental work purporting to disprove this explanation has not (to my knowledge) been confirmed.

6. It is suggested that differences in results of ureteral obstruction may be due to the age of the animal; incidence of infection; degree of venous obstruction, and the method and site of obstruction.

7. The theory that muscular insufficiency causes hydronephrosis is unsupported by convincing evidence.

8. Congenital absence of a ureter cannot be a cause of hydronephrosis.

9. Abnormal renal mobility; anomalies of the blood vessels, obliquity of ureteral insertion and the presence of accessory ureters have all been proposed as etiologic factors in hydronephrosis, but are inadequately supported by convincing evidence.

10. The normal stenosis of the ureter is described, and the development of our knowledge of it is reviewed. Persistence of fetal irregularities has been neither proved nor disproved as a cause of congenital hydronephrosis.

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27. Braasch, W. F.: Dilatation of the Ureter and Renal Pelvis, J. A. M. A. 73:731 (Sept. 6) 1919; Collected Papers, Mayo Clinic, 1919, p. 248.

11. Mechanical irritation and infection have been advanced as causes of acquired ureteral stricture. The frequent occurrence of secondary infection in hydronephrotic kidneys obscures the etiologic significance of evidence of infection when it is observed in specimens.

12. In Case 1, no vestige of a ureter could be found. The low specific gravity and high coagulable protein content of the fluid in the sac make it probable that the fluid was more a transudate than urine. Its accumulation in the sac is ascribed to an edema-producing mechanism, partly osmotic and partly due to venous obstruction.

13. In Case 2, no anomalies of position or blood supply were found to explain the hydronephrosis. The ureter showed a marked stenosis immediately below the ureteropelvic junction. It is believed that the few infiltrating cells and fibrosis of the submucosa do not prove that the lesion was inflammatory in origin.

14. Postoperative thrombosis in the left leg of the 8-year-old patient is reported as a rare circumstance in so young a person.

OPERATIVE TREATMENT OF RECENT FRACTURES AND NONUNION

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The prophylactic treatment of ununited fractures is of interest to all, and, while there are numerous other factors that should be considered, the early open operation, with the application of any type of nonabsorbable internal splint, is one very definite cause of nonunion. Time prevents consideration in this paper of any other type of open operation, though there have been many recent improvements in early operative methods. Treatment with the Lane plate was selected not only because it is most frequently employed but also because probably the results of its employment are the most disastrous of the usual methods.

Inadequate fixation; too many readjustments; the wide separation of the fractured ends; the interposition of muscle, or a loose piece of bone, between the fragments; the lack of active and passive motion; interference with the blood supply; sclerosis of the end of the bones; infection; obstruction to, or impairment of, lymph circulation; perhaps some of the constitutional diseases—all should be considered in any report of either delayed union or nonunion of bone. But in this study we are interested only in the effects of an early open operation with the application of a nonabsorbable internal splint in its relationship to ununited fractures.

We are not employing the terms "nonunion" and "delayed union," for in 1914, when our experimental work was started, these terms were not in vogue.

Following Lane's revival of the then almost extinct metal plate, there were, of course, many open operations done early. As a result of this teaching, there were some reports, and many more cases of ununited fractures.

This practice of early open operation is still prevalent in certain parts of America, and one of the reasons for its continuation is to be found in the increased misuse of the roentgen ray; for some surgeons apparently do not realize that a "bad roentgen-ray result" will frequently give an excellent functional limb. Another reason may, perhaps, be found in the fear of law suits; for, in the hands of an unscrupulous lawyer, a roentgenogram showing the fragments not perfectly approximated is a dangerous exhibit to have presented to an average jury, no matter how excellent the functional result that the patient might have obtained.

Of course, everyone will admit that there are some cases in which an early open operation, occasionally with the employment of some foreign

material as an internal splint, has to be performed, but these should be the exceptions.

We have studied this association between early operative interference and ununited fractures by the three usual methods, experimental, theoretical and clinical.

EXPERIMENTAL DATA

Group I. In 1914, under ether anesthesia, we broke the humerus in fifty Belgian hares. There were eleven rabbits transferred to Group II, as will be shown later, because, in the process of breaking the legs, the skin was opened, and only those animals having a simple fracture were placed in Group I. We, however, continued until we obtained the fifty above mentioned. These animals were then placed in pens by themselves, so that there could be no injury from other rabbits. A plaster cast, which was placed around the leg and the body of the rabbit, extended to both front and back legs, so that the rabbit could not release himself from the cast. As a rule, the right front leg was employed, and the cast took in also the left hind leg. The cast remained on for four weeks.

Out of the fifty animals, eight died from various causes. In six months' time, the remaining animals were killed. Of the forty-two, there was bony union in thirty-one (about 74 per cent.).

Group II. The humerus in twenty-five Belgian rabbits was exposed and fractured by bone forceps, and the wound closed. After the operation, sterile dressings, and a cast as employed in Group I, were applied. In ten days, the cast was opened; the skin stitches were removed and another cast was applied. All infected animals were discarded at this time. At the end of a month the second cast was removed. For the remainder of the six months, the rabbit had no dressing. In addition to these twenty-five animals, there were the eleven transferred from Group I, which had a similar dressing applied. Of these thirty-six, nine were discarded on account of infection, etc., leaving twenty-seven, which were killed at the end of six months. Nineteen of the twenty-seven had firm bony union (about 70 per cent.). The alinement in all nineteen was fair.

Group III. The humerus was exposed in fifty rabbits, and then fractured by bone forceps. A small steel plate modeled after the Lane's plate was nailed in as an internal splint. The metal plate was made out of the so-called "tool" steel, and fashioned as nearly like the Lane plate as possible. We found it practically impossible to insert the small screws, so we employed serrated brads which were about as long as the femur was thick. The same type of dressing, etc., employed in Group II was used.

Death occurred in seven of this group, from unknown causes. Infection, and working out of the plate, occurred in twelve. At the end of six months, the remaining thirty-one rabbits were killed, and bony union was found in twelve, (about 30 per cent.). The nineteen without bony union showed practically no callus around the plate and relatively little on the side opposite the plate. The alinement in twenty-two out of the thirty-one was good, though the nails and plates had worked loose in thirty cases.

Alizarin was fed to about half the animals in all three groups, but the color index, as shown in the necropsies, was not constant and of very little help. Animals fed alizarin did not seem to show callus by roentgen ray any earlier than those without this chemical. Apparently, the alizarin did not in any manner injure or upset the rabbits. The staining of the newly formed bone cells was extremely interesting, and the giving of alizarin is worthy of further study.

In these experiments, there were no roentgen rays used, other than those employed to try to demonstrate whether animals fed alizarin showed callus earlier or not, and no microscopic sections were made; for, at that time, we were interested only in ascertaining whether the metal plate interfered with union or not.

The remainder of the report of this series of experiments [1] had to do with (*a*) union of fractures with graft as compared with union with plate; (*b*) union with infected graft as compared with infected plate, as well as (*c*) the effects of autogenous graft placed in the epiphysial line in the young and undeveloped, as compared with a metal screw placed in the same locality.

Group I. Simple fractures:	
Number of rabbits examined at end of six months	42
Number having bony union	31
Approximate percentage of bony union	74
Group II. Compound fractures without plate:	
Number of rabbits examined at end of six months	27
Number having bony union	19
Approximate percentage of bony union	70
Group III. Compound fractures with plate:	
Number of rabbits examined at end of six months	31
Number having bony union	12
Approximate percentage of bony union	30

THEORETICAL DATA

So much has been written on the repair of fractures and particularly on the part played, or not played, by the periosteum in this process that it would carry us far beyond the scope of this paper to try to analyze the

1. Ann. Surg., June, 1915.

literature of even the past two years. There has been no theory advanced that would seem to indicate that trauma to the periosteum, such as is necessary in any open operation, could be other than harmful. Certainly Ely [2] has clearly demonstrated that nonunion is to be expected if the periosteum is divided circularly. The average surgeon, by means of traction clamps and other similar instruments, is very apt to succeed in breaking the periosteum around the entire circumference of the bone. If he does not do this, he at least not only makes a slit in the periosteum, but also places in a metal plate to keep this slit open; and, as Ely has also shown, "when the periosteum is slit, bony union may or may not take place." Also, if the theory advanced so admirably by Bancroft [3] of an extracellular deposition of calcium salts is correct, a plate would tend to interfere with these deposits "in the avascular zones between the blood vessels."

All writers on the subject of bone repair agree on the important rôle played by the early formation of new blood vessels, and Eliason [4] demonstrated that the frequency of nonunion in the lower end of the tibia was due to the ease with which the nutrient vessel could be injured. In the application of a plate, the surgeon runs a great risk of injuring blood vessels, sometimes even the nutrient vessel.

CLINICAL DATA

Of the thirty-two cases of ununited fractures that have come under my observation, twenty-three, or about 70 per cent., had had an early open operation. Of the twenty-three, I had operated early on eleven.

On looking over the literature, certainly the largest group to be found is that of Henderson,[5] in which he reports 211 cases of nonunion, not including delayed union. In analyzing this report, one finds that there had been a previous open operation in 108 of 163 cases, or about 66 per cent. He does not mention whether there had been a previous operation in the remaining fifty-eight or not, nor does he mention how soon after injury any of these primary operations were performed, though it is fair to assume that most of them were relatively early.

Number of ununited fractures Jefferson Hospital, Roanoke, Va.....	32
Number of patients having had previous operations.....	23
Approximate percentage having had previous operations.....	70

2. Ely, L. W.: Healing of Fractures, Arch. Surg. **5**:527 (Nov.) 1922.

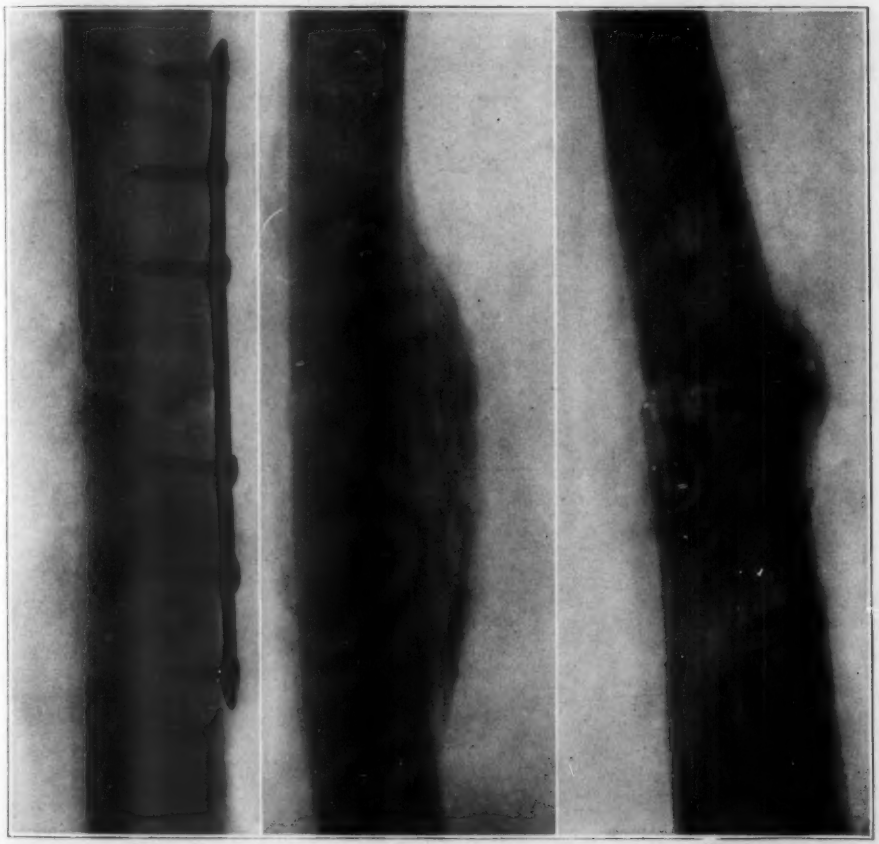
3. Bancroft, F. W.: Bone Repair Following Injury and Infection, Arch. Surg. **5**:646 (Nov.) 1922.

4. Eliason, E. L.: Surg., Gynec. & Obst. **33**:551 (Nov.) 1921.

5. Henderson, M. S.: Nonunion in Fractures, Massive Bone Grafts, J. A. M. A. **81**:463 (Aug. 11) 1923.

Number of cases of nonunion, Henderson's report, Mayo Clinic	211
Number in which previous operation was mentioned	163
Number in which previous operation was performed	108
Approximate percentage having had previous operations	66

In these days, when every clinic is looking for focal infections, a buried foreign body, such as a Lane plate, should not be forgotten. We have had two cases in which there was pain in first one joint and



A B C

Fig. 1 (Case 1).—Ununited fracture of the femur: *A*, plate applied sixty-six days previously (the position of callus and the fact that plate is holding fragments apart may be observed); *B*, thirty-two days after removal of plate, with callus on opposite side from which plate was removed; active and passive motion guarded; *C*, three months after removal of plate; good function had resulted.

then in the other, and in which other symptoms of a low-grade infection were shown as well, completely relieved by the simple removal of a foreign body; one had had a Lane plate buried for four years and the other had acted as host for a piece of silver wire for more than

ten years. At the time of removal neither of these cases showed the presence of any pus, but in each the foreign body was surrounded by a pool of straw-colored fluid, which was probably toxic, in spite of negative smears and cultures.

The possibility of a late osteomyelitis followed by a pathologic fracture has been recognized in many clinics, and one such case came to our

A B C

Fig. 2 (Case 2).—Ununited fracture of humerus: *A*, thirty-one days after application of plate (plate too small); no union; no infection; *B*, two months after removal of plate (bone atrophy on side to which plate was applied, and callus on opposite side may be observed); *C*, six months after removal of plate.

attention nine years after the application of the plate. Healing and bony union followed the removal of the plate and sequestrums with drainage.

The four cases which are illustrated will perhaps be sufficient to demonstrate some of the bad results following the use of Lane's plate,

certainly sufficient to show the effects of the plate on the deposition of callus.

CASE 1.—*Ununited fracture of femur.* Lane's plate was applied to the femur sixty-six days previously. The absence of callus may be noted as well as the

A B

Fig. 3 (Case 3).—Ununited fracture of femur: *A*, plate applied thirty-eight days previously; *B*, twenty-one days after removal of plate. The filling up of callus is probably due to the pushing aside of the callus, etc., in the process of removing the plate.

fact that the plates hold the fragments slightly apart. No infection was found at the time of removal of the plate (Fig. 1, *A*).

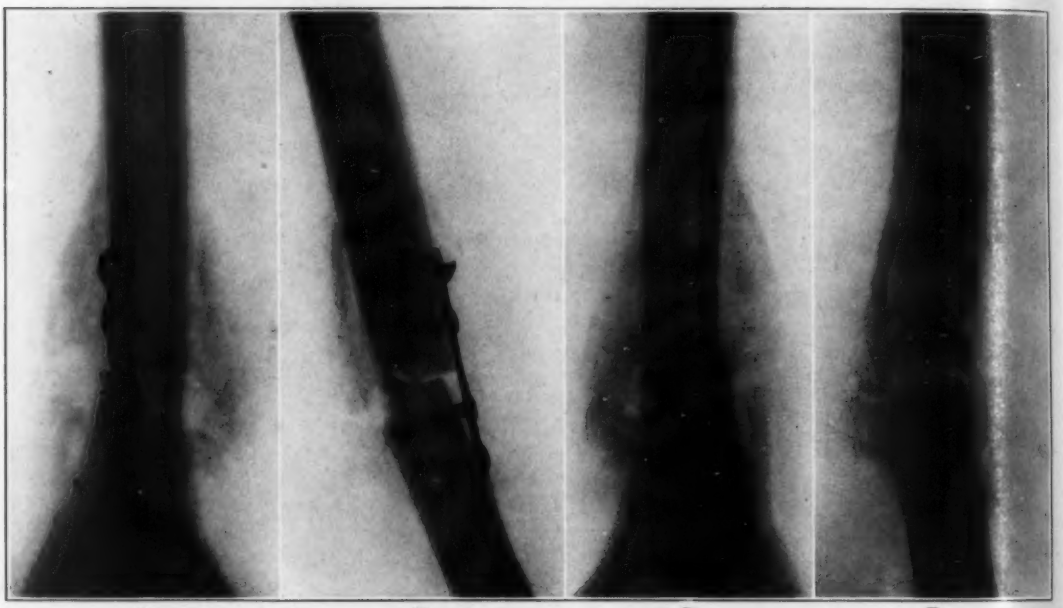
Figure 1, *B* is a roentgenogram taken thirty-two days after removal of the plate. In addition to removal of the plate, active and passive motion was

guarded, the patient wearing a light brace. The immense amount of callus on the side opposite that from which the plate was removed may be noted.

Figure 1, *C* is a roentgenogram taken three months after the removal of the plate. The patient had good function and firm bony union.

CASE 2.—*Ununited fracture of humerus.* A Lane plate which was too small was applied to the humerous. The roentgenogram (Fig. 2, *A*), made thirty-one days previously, shows absence of callus. There was no union in spite of the fragments being in good alinement. No infection was present when the plate was removed. All screws were loose.

A roentgenogram (Fig. 2, *B*), taken two months after removal of the plate, shows not only the absence of callus on the side from which the plate was removed, but also the bone atrophy, which was probably due to Lane's plate.



A B C D

Fig. 4 (Case 4).—Ununited fracture of humerus: *A*, sixty-four days after application of plate; *B*, lateral view (plate is holding fragments apart); *C*, forty-one days after removal of plate; *D*, lateral view.

Figure 2, *C* is a roentgenogram taken approximately six months after removal of Lane's plate. The patient at this time had an excellent result, with firm bony union.

CASE 3.—*Ununited fracture of femur.* Lane's plate holds the fragments somewhat apart in Figure 3, *A*. Absence of callus may be noted. The primary operation was performed thirty-eight days previously. No infection was present at the time of removal of the plate.

Twenty-one days after removal of plate, there was a great amount of callus on the side opposite that from which Lane's plate was removed (Fig. 3, *B*). The callus was evidently doubled on itself owing to injury during the removal of the plate.

CASE 4.—*Ununited fracture of humerus.* Figure 4, *A* is a roentgenogram taken sixty-four days after application of Lane's plate.

Figure 4, *B* is a lateral view taken on the same date. Lane's plate holds apart the fragments in spite of the screws having worked loose.

In Figure 4, *C*, a roentgenogram taken forty-one days after the removal of Lane's plate; the large amount of callus on each side of the bone may be seen.

In Figure 4, *D*, a lateral view taken on the same date, the callus on the side opposite that from which the plate was removed may be noted.

Approximately six months after removal of the plate, the patient had firm bony union, with fair functional result.

CONCLUSION

The conversion of a simple fracture into a compound fracture is warranted only in the very exceptional case, and the employment of a nonabsorbable internal splint is an additional factor in the production of ununited fractures.

These metal appliances should be removed even in the presence of firm bony union for they frequently give rise to late local trouble, such as osteomyelitis, and occasionally to constitutional symptoms, which disappear after removal of the foreign body.

CARCINOMA OF THE KIDNEY

REPORT OF FOUR CASES

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The four cases of carcinoma of the kidney reported here illustrate four different pathologic types, which not only have points of interest, but also present certain problems in the matter of diagnosis, the importance of which seems to justify their presentation.

It should be mentioned that though it is an indisputable fact that the cases of hypernephroma far outnumber those of carcinoma, generally considered a rare disease of the kidneys, urologists should be most careful in making a diagnosis, swayed as they may be by preconceptions of the frequency of one disease and the rarity of the other. And what makes it doubly important that a correct diagnosis be established is that with early recognition of malignancy, no matter where it may occur, early surgical treatment will result in a higher percentage of cures.

The importance of hematuria as a symptom of malignant disease in the urinary tract has been emphasized many times, but the emphasis can never be considered exaggerated if we would increase our number of cures. The problem of determining the origin as well as the cause of hematuria may not be a simple one, and particularly is this the case in those instances in which the renal neoplasm is small—a condition present in two of the four cases reported in this paper. Furthermore, these two cases illustrate the value of pyelograms in this type of case; namely, when there is painless and symptomless hematuria and a careful physical examination has been negative as to outstanding points.

In two of the cases, as the roentgen-ray examination revealed calculi, a preoperative diagnosis of nephrolithiasis was made, the presence of tumor not being suspected.

Our failure to recognize the tumor in Case 4 was due to the fact that it was very small and was located in the hydronephrotic sac. No pyelogram was made in this case; and it is extremely doubtful whether it would have yielded us information from which the presence of the small tumors could have been recognized. It is fair to assume that the small tumors in an extensive hydronephrosis would not have produced a change in the pyelogram sufficient to justify a diagnosis of tumor.

In Case 3, pyelograms were not made because it appeared self-evident that the patient was suffering from bilateral renal lithiasis. During physical examination, on palpation the right kidney was very hard, but its surface was smooth. It was freely movable, and the presence of a tumor was not suspected.

REPORT OF CASE

CASE 1.—*History.*—Mr. A., aged 52, referred by Drs. Wilbur Post and Wm. Thomas, gave a negative family history. He complained of pain in the right lumbar region, renal colic, hematuria, nausea and vomiting. Prior to 1918, he was essentially well. In April, 1918, several deep-seated boils appeared over his body, which cleared up in about two months under vaccine treatment. During the fall of 1918, four teeth and the tonsils were removed as possible foci of infection causing the furunculosis. In November, 1921, pain suddenly developed in the right lumbar region, so severe that it awoke the patient from his sleep. It continued for two hours, radiating to the front of the abdomen and to the upper part of the groin. No morphin was required at that time. Previous to the onset of this severe pain, a dull ache and a feeling of discomfort in the right lumbar region were symptoms.

Fig. 1 (Case 1).—Filling defect involving inferior calyx.

About thirty minutes after the pain had stopped, the patient noticed that the urine was distinctly bloody, and contained clots of blood. The following day, he had a second attack, less severe. Blood was noted in the urine at various times thereafter. Affer his tonsils were removed, there was more or less blood in the urine continuously. Sometimes only red blood cells were found microscopically; sometimes the urine was very red, and at other times there were clots, the passage of which was accompanied by renal colic. The last appearance of blood in the urine followed a moderate attack of influenza.

Examination.—The patient was well nourished, and not acutely ill. The left eyelid was inflamed and swollen, and there was some injection of the conjunctiva. The heart and lungs were normal. The reflexes were normal. Examination of the kidneys, ureters and bladder and external genitalia was negative. The rectal examination was also negative.

Blood examination revealed: erythrocytes, 5,000,000; leukocytes, 16,800; hemoglobin, 88 per cent. The blood pressure was 130, systolic; 66, diastolic.

Roentgen-ray examination revealed a small, round shadow in the bony pelvis. There was no other positive evidence of stone. To determine whether this shadow-producing body was in the ureter, and whether it should be excluded as a factor in the production of the hematuria was of importance.

Cystoscopic examination was made, March 18, 1922. The cystoscope was introduced without difficulty of obstruction. A small, notch formation was seen above. The margins of the sphincter were normal, as were the bladder and

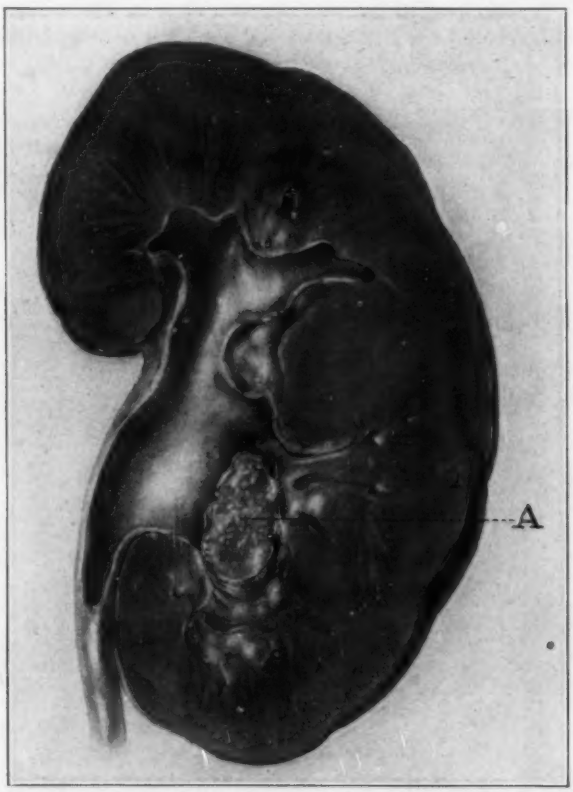

Fig. 2 (Case 1).—Primary carcinoma of kidney.

ureteral orifices. The left catheter passed all the way to the kidney pelvis without difficulty or obstruction. The right catheter met an obstruction about 1.5 cm. above the right ureteral orifice. Eight catheters were used, but the obstruction could not be passed. Because of failure to overcome the apparent obstruction to the catheter on the right side, a second cystoscopy was performed, May 8. The left catheter passed up without difficulty or obstruction. A No. 4 catheter was passed on the right side without difficulty, and thereafter a large No. 6 catheter was passed into the kidney pelvis.

Urine collected for examination revealed: bladder, cells eighty, urea 0.8; right kidney, cells 430, urea 0.3; left kidney, cells 220, urea 0.9.

Pyelography (right side) revealed a filling defect involving the region of the inferior calyx; that is, complete absence of the inferior calyx. The margin of the defect was very clear-cut, and slightly cresentic in outline. The pelvis proper was normal. A diagnosis of tumor of the kidney, involving the region of the inferior calyx, was made, and operation was advised.

Operation (November 1).—Under ether anesthesia, the usual oblique incision was made, and the kidney was delivered through the incision. At the time of operation, the kidney appeared normal. No signs of tumor were evident. In view of the fact that a diagnosis of tumor had been made, it was decided to perform a nephrotomy. A tumor was disclosed in the lower pole of the kidney, and a nephrectomy was performed.

Gross Pathology.—The kidney appeared normal in size, shape and color, weighing 190 gm. The capsule stripped easily except at an infarct area where it was adherent. The cortex was normal in color except for some petechial hemorrhages where the capsule was torn off. A cross-section revealed that the cortex was normal. The kidney markings were normal. The pelvis was normal in size and shape. The middle and superior calices were normal. A small tumor, about 1.5 cm. in diameter, firm, red and unbroken, extended into and filled the inferior calyx. It arose on a broad base from the kidney substance near the inferior calyx (Fig. 1).

Outcome.—The patient made an uneventful recovery. He died, Feb. 10, 1924. Partial necropsy showed metastatic carcinoma of the second lumbar vertebra.

Case 2.—*History.*—Mr. C., aged 50, referred by Dr. George Coleman, gave a negative family history except for the fact that one brother died of cancer of the bladder. The patient complained of blood in the urine and frequency of urination. Seven weeks prior to examination, he was riding in an automobile when the brakes and engine failed and his car rolled down a hill into an embankment, giving him a severe jolt, directed against the small of the back. He felt faint, and lay down on the ground on a robe. A drink of water relieved him. No aches, soreness or pain were present after the accident, but before going to bed he noticed that the urine was bloody.

The day following the accident, the urine was again bloody; bright red at first, gradually becoming darker. Three weeks after the accident, lifting heavy boxes was followed by the appearance of blood in the urine. This symptom was present, more or less constantly, thereafter.

Examination.—The physical examination, including examination of the kidneys, ureters, and bladder and rectal examination, was negative.

The blood examination revealed: leukocytes, 5,800; hemoglobin, 98 per cent. The blood pressure was 180 systolic, 98 diastolic. Blood chemistry determinations revealed: urea, 34.0; uric acid, 5.2; creatinin, 1.65; nonprotein nitrogen, 33.

The roentgen-ray examination was negative. Cystoscopic examination revealed the presence of a small median bar, but was otherwise negative.

Urine obtained by catheterization showed: bladder, cells, 210; staphylococci on culture; right kidney, cells, 40; sterile to culture; left kidney, cells, 10; sterile to culture.

A pyelogram of the right side showed a rather large kidney pelvis, with superior calyx, definitely broadened. Near its upper pole, there was an area of decreased density suggesting a lack of filling in this area. A second pyelogram was made a few days later to determine whether or not this filling defect could be demonstrated again (Fig. 3).

A diagnosis of tumor of the kidney pelvis was made.

Operation.—Under gas-ether anesthesia, the usual lumbar incision was made on the right side. The kidney, which was easily isolated from its bed and delivered through the incision, appeared perfectly normal. A nephrectomy was performed.

Outcome.—The patient made an uneventful recovery.

Gross Pathology.—The kidney weighed 152 gm. The outside was yellow-brown. The convex border was a little pitted in places. When the capsule was removed, a smooth surface remained. In the upper pole of the renal pelvis, and apparently attached to the base of one of the calices, was a soft, polypous, gray-

Fig. 3 (Case 2).—Filling defect in superior calyx.

red tumor mass about 2 by 1.3 by 0.6 cm. The pedicle was rather broad and had a maximum transverse diameter of 1.7 cm. The renal pelvis was not dilated. Its lining was gray, strippled in places with small petechial hemorrhages. The inside of the kidney was yellow-brown. The cortex had a maximum width of 8 mm. The cortical striations were fairly indistinct. The maximum width of the entire parenchyma was 2.3 cm. In comparison with the yellow-brown cortex, the pyramids were a rather dark pink.

Microscopic Examination.—The sections consisted of dense masses of carcinoma cells in papillary arrangement, with a small amount of connective tissue and a few areas of necrosis with polymorphonuclear leukocyte infiltration. The typical individual cell was rather small, with an indefinite cell body and a round vesicular nucleus.

CASE 3.—*History.*—Mrs. L., aged 56, referred by Dr. Rollin T. Woodyatt, gave a negative family history. She complained of a pain in the right lower abdomen; a mass in right lower abdomen; blood in the urine; constipation; fatigue, and pain in both hip joints.

She had been frail from early childhood but always forced herself into physical activity. About eight years prior to examination, when she was 48, she was troubled with gas in the bowel, and passed much flatus, which had no odor. At intervals, loose stools were passed; and again she was constipated, but not severely. At no time had black, tarry or bright red stools been noticed. Bowel distress had been constant in varying degrees of severity for the past eight years. On a few occasions, there had been such severe cramps that it was impossible to move the bowels. The last seizure occurred in the early summer of the preceding year. When the patient lay quietly the distress was relieved, the maximum amount of comfort resulting from lying on the back. Six weeks prior to examination, while she was lying down to ease her pain, an unusual pressure in the right side was noticed, but this disappeared when she stood up. Certain positions in recumbency brought the fulness out more distinctly. There were no urinary symptoms.

Examination (Dr. Woodyatt).—There was a tumor mass in the right side of the abdomen, between the liver above the brim of the pelvis and the midline, on the left, and extending as far as possible to the right. This tumor was rough, ovoid, firm and resilient. It could not be moved much up and down, but could be pushed across to the left; and as the patient lay on the back, a hand under the back below the rib margin and one on the abdomen permitted the mass to be moved dorsoventrally. It was tender in spots. The introitus was wide; the os was small. The body of the uterus was not felt anteroposteriorly but appeared to be retroposed in the hollow of the sacrum.

Blood examination revealed: erythrocytes, 4,510,000; leukocytes, 7,300; hemoglobin, 80 per cent. The blood pressure was 140 systolic, 85 diastolic.

Roentgen-ray examination revealed a large "soft-parts" shadow on the right side corresponding to the kidney; on the left, a large kidney shadow, also. A dense shadow on the left side at the level of the third lumbar was compatible with stone in the kidney pelvis. On the right side, there was a much larger shadow, very dense and a little irregular in outline, which was compatible with a kidney stone in spite of its enormous size. Below this shadow, overlying the crest of the ilium, there was a group of small rounded shadows, about a dozen, which may have been the shadows of stone or calcified glands. There was a faint shadow overlying the last rib on the right side.

Cystoscopic examination revealed a moderate cystocele. The internal urethral orifice was irregular in outline, and appeared to be more vascular than normal. In the bladder base, on the left side, near the internal urethral orifice, there were large vessels, both arteries and veins. Catheterization of ureters revealed no obstruction. There was a free flow of urine from the left catheter; none from the right. The phenolsulphonephthalein test revealed: right, no dye; left, time of appearance, five minutes; first half hour, 11 per cent.; second half hour, 17 per cent.; total, 28 per cent. Urine collected showed: bladder, cells, fifty-nine; left kidney, cells, five; all culture sterile.

Operation (March 26, 1923).—Under ether anesthesia, the usual oblique lumbar incision was made over the right kidney, which was freely movable and easily delivered. The fatty capsule was divided, and the kidney was found to be three times the normal size, very irregular in outline and very hard in consistency. The ureter was ligated separately, isolated and divided between two

ligatures. Before the pedicle was ligated, a careful inspection of the wall was made, which showed that the vena cava was in the mass of infiltrating tissue around the renal pedicle and the tumor. This was carefully separated from the tumor mass. The pedicle was ligated and the tumor removed.

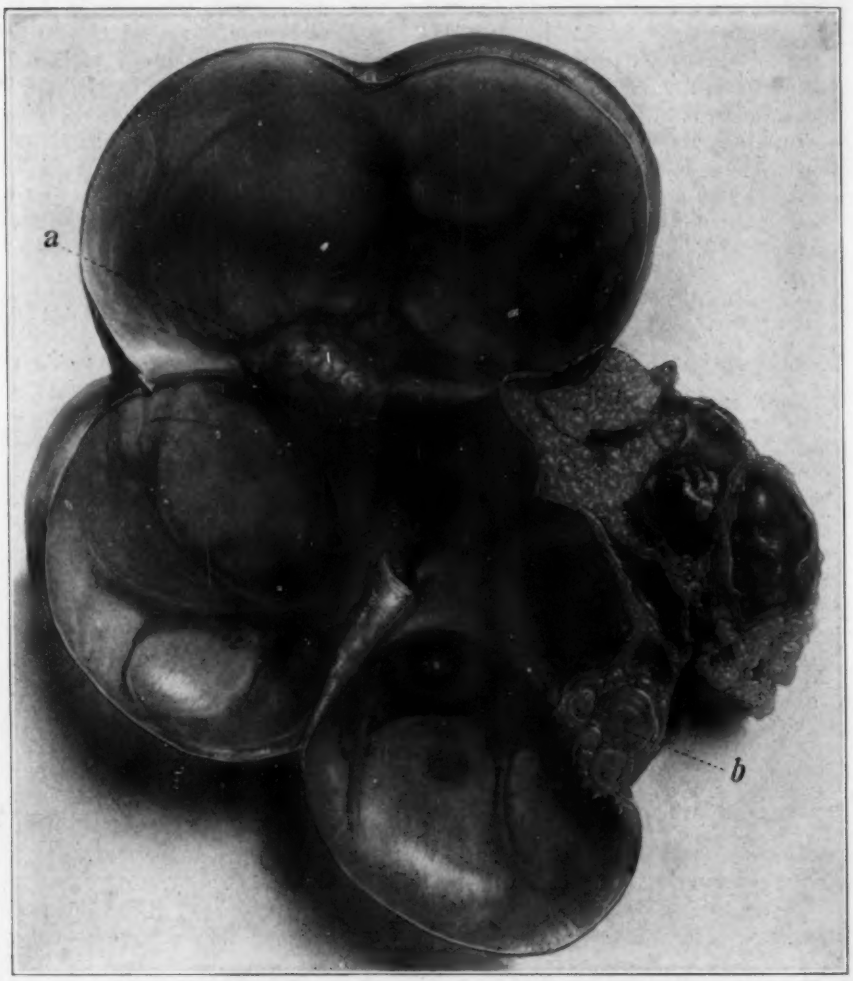

Fig. 4.—Carcinoma (*a*, *b*), and stones in pelvis.

Outcome.—Convalescence was uneventful. The patient left the hospital on the thirty-seventh day after operation, and died at her home about four months later.

Gross Pathology.—The weight of the kidney and attached perirenal tissue was 475 gm. The mass measured 13 by 8 by 7.5 cm. The surface was rough and mottled with small subcapsular hemorrhages. There were numerous small retention cysts which discharged a thin, chocolate colored fluid when opened. Around the pedicle and completely surrounding and burying the pelvis were

large masses of yellow-white tissue which were fairly hard. They occurred in groups of coalescing nodules, and cut with only slightly increased resistance On longitudinal section the following picture was presented: The cortex was greatly thickened, averaging 1.4 cm. The medulla was thinned by a greatly dilated pelvis and calices. In the center was a large mass of yellow-white tissue surrounding the pelvis and replacing the medulla, 5 by 3 cm. on cross-section. It was hard and cut with slightly increased resistance; showed a tendency toward striations and trabeculation, and was apparently invading the kidney cortex. A few discrete nodules, about the size of a small cherry, that had all the characteristics of the larger mass, including the striations, were present in the cortex. Plugs of caseous-appearing material were expressed from these nodules. Lying in the dilated pelvis was a large stone, 6 by 2.7 by 2 cm., the surface of which was extremely spiculated. The walls of the pelvis, which were slightly roughened, were white, with small petechial hemorrhages, and covered with a flocculent necrotic material.

Microscopic Description of Specimen.—The kidney tissue appeared riddled with nests of epithelial tissue, singly and in groups. The typical cell was a large one with large, pink-staining nucleus. There were a few areas resembling pearls; large areas of round-celled infiltration, and several, large, gland-like areas in which cysts were lined with multiple-layered epithelium. Diagnosis was made of kidney carcinoma, probably squamous celled.

CASE 4.—*History.*—Mrs. D., aged 54, referred by Dr. J. R. McClellan, had been troubled with pain in the abdomen off and on for the last twenty years. One brother died of cancer of the heel.

The patient complained of pain in the left side. The first attack lasted a month or more. It did not recur for ten years, but after that it was fairly frequent. The last attack of pain began three weeks prior to examination, at a time when the patient was working harder than usual, the recurrence being attributed to this. It was dull and throbbing, located in the left lower part of the abdomen and in the side, and would remain for about one minute, then disappear for three to five minutes, when it would begin again. Pain was never felt in the back. Certain positions seemed to increase the pain, but these positions could not be described by the patient. The pain was not distinctly worse at the end of the day. There was no nausea or vomiting. Massage was resorted to as a relief. There were no acute abdominal cramps. No blood was noted in the urine. Excessive urination at night was rare. The attacks were associated with depression. The patient was morose and cried easily for no known cause. Depression was not always present, but had attended the last attack.

Examination.—The patient did not appear ill. The tonsils were jagged. The heart and lungs were normal. The abdomen appeared normal on inspection, but on palpation a tumor mass was felt in the left upper quadrant, which occupied practically the entire quadrant, extending 2.5 cm. beyond the midline and about 2 cm. below the level of the navel. Above, it extended under the ribs. In appearance it was smooth. Its margins were round and it was of firm consistency. It moved on respiration but could not be moved about. The liver, spleen and right kidney was not palpable. No tenderness was noted when the region of the kidneys was struck hard. There was slight pitting about both ankles. The reflexes were normal.

Blood examination revealed: leukocytes, 12,400; hemoglobin, 85 per cent. The blood pressure was 160 systolic; 110 diastolic.

Roentgen-ray examination revealed a calculus in the left kidney. The cystoscopic examination was negative. In the phenolsulphonephthalein test, the

dye appeared from the right kidney in seven minutes; from the left kidney, not at all.

Operation.—Under ether anesthesia, the usual lumbar incision was made; the muscles and facia were divided, and the fatty capsule of the kidney was opened. The kidney was bound to surrounding structures by much fibrous tissue and was of enormous size. On account of its size and the adhesions, it was with the greatest difficulty that it was finally delivered through the wound. Structures of hilum were tied off en masse with three separate ligatures of catgut.

Gross Pathology.—The specimen measured 13 by 8 inches (32.5 by 20 cm.). The surface was smooth. Section of the specimen revealed a large hydronephrotic sac. The secreting kidney tissue had practically disappeared. The pelvis was enlarged, and the walls were thickened. Roentgen-ray examination of the pelvis revealed calculi. The peripelvic fat was much thickened. Further examination of the hydronephrotic sac revealed a tumor in the upper part that was 1 inch by 1¼ inches (2.5 by 3.1 cm.). The surface was irregular and the tumor of firm consistency. A similar papillary tumor measuring 1 inch by 1¼ inches was found in the lower part of the kidney.

Microscopic examination of a piece removed from the tumor designated, as *a* in Figure 4 revealed carcinoma.

Second Hospital Admission.—After the operation, the patient returned to her home in the south. She enjoyed good health until January, 1918, at which time she began to complain of pain in lower left side; with much tenderness over the ascending colon. An exploratory operation revealed recurring carcinoma.

SUMMARY

These four cases illustrate several points in diagnosis:

1. The ease and accuracy with which tumors of the kidneys may be recognized by the use of pyelography, even though the tumors are small. They further demonstrate the ease with which tumors are overlooked, their existence not being suspected because of the presence of other very obvious lesions, such as stone.

2. The value of complete, careful and accurate study in all cases of renal hematuria.

3. The varying pathologic types of renal carcinoma that may be met in a small series of cases.

STUDIES IN EXHAUSTION: VII. AUTOINTOXICATION

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A state of autointoxication may result (*a*) from the retention of waste products; (*b*) from arrested catabolism, especially of proteins; (*c*) from the formation of certain complex substances as the result of faulty action on the part of some organ; (*d*) from toxic substances, presumably produced by intestinal bacteria, which are absorbed when normal elimination is completely arrested as in acute intestinal obstruction. Whatever its apparent cause, however, the outstanding symptoms in each case are the same, lassitude, increasing debility, and psychic disturbances which vary from nervous irritability to delirium, headache, and slight fever. Why any of these causes should produce these symptoms has not been clear. In this connection, a recent writer on this subject makes the following statements:[1]

"We are still uncertain concerning the precise cause of the symptoms in prolonged anuria. . . The possibility of an autointoxication from the absorption of injurious compounds in the large intestines has given rise to much discussion. Is such an autointoxication responsible for the symptoms of chronic constipation? On this question opinions differ. . . Amino-acids may be increased in the blood and urine in diffuse hepatic disease; but we know nothing of their relation to the toxic symptoms which are at times observed in this condition. . . Intestinal obstructions involving the duodenum and the upper jejunum are serious and often rapidly fatal. In spite of much experimental study the exact cause of death in such conditions is not settled . . . ,

The identity of these symptoms with those of exhaustion from the causes already reported led us to consider that the primary cause must also be identical in each. We therefore selected certain end-products of intestinal digestion, the feces, and two derivatives from the feces, indol and skatol; an amino-acid, leucin; a product of protein catabolism, peptone; and intestinal toxins induced by artificially produced obstruction, studying the effects of each by the same group of methods as that employed in the other phases of this research.

A. Histologic Studies

Feces Extract: Indol and Skatol.—In each of two animals—cats—2 c.c. of feces extract were injected in the vena cava. One was killed one minute and the other 10 minutes after the injection. In the former, the Purkinje cells were hyperchromatic; in the latter, nearly all the Purkinje cells were markedly fatigued.

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1. Hewlett, A. W.: The Oxford Medicine, London, Oxford University Press **1**:60-66, 1920.

No other examinations of the brain cells after the injection of feces extract have been made. However, an extensive series of histologic examinations of the brain and of other organs and tissues after the injection of indol and skatol has been made. In these early experiments, in which only the brains were examined, the progressive effects of the injection of indol and skatol were as follows:

1. Animal killed ten minutes after the injection: Most of the brain cells hyperchromatic and active with only a few fatigued cells.

2. Animal killed thirty minutes after the injection: A few brain cells hyperchromatic; nearly all fatigued.

3. Animal killed forty minutes after injection; no hyperchromatic cells; nearly all fatigued.

The histologic findings in later experiments are given in Table 1 (Fig. 1).

Leucin.—The early effects on the brain cells of the injection of leucin are shown in the histologic examination of the brains of two animals, one killed forty-five minutes, the other one hour and forty minutes after the injection. In the former, most of the brain cells were hyperchromatic, only a few fatigued; in the latter, most of the brain cells were fatigued.

The later effects of the injection of leucin are listed in Table 2. Examination of other organs and tissues revealed no histologic changes.

Peptone.—The histologic effects of the injection of peptone on the central nervous system, the liver and the suprarenals are shown in Table 3 (Figs. 2-4). In these two experiments, the examination of other organs and tissues, such as the spleen, voluntary muscle, intestine, testicle and thyroid gave no evidence of differentiation from normal tissues.

Intestinal Obstruction.—In a group of animals, loops of the small intestine were ligated by the methods described in detail in a previous publication,[2] and an extract made from the isolated portion was injected into other animals. The destructive effect on the brain cells is shown in Table 4.

Summary of Histologic Findings.—The injection of feces extract, of indol and skatol, of leucin, of peptone, of an extract of isolated loops of intestine, produces histologic changes in the central nervous system which vary with the length of retention of the cultivating agent, the early effect being a hyperchromatic condition progressing to fatigue and exhaustion as the length of time after the injection increases.

These agents also produce changes in the suprarenals which are most marked in the cortex. Peptone and leucin produce marked histologic changes in the liver which, however, is practically unaltered by the injection of skatol and indol.

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2. Crile, G. W.: Anemia and Resuscitation, New York, D. Appleton & Co., 1914, pp. 150-194.

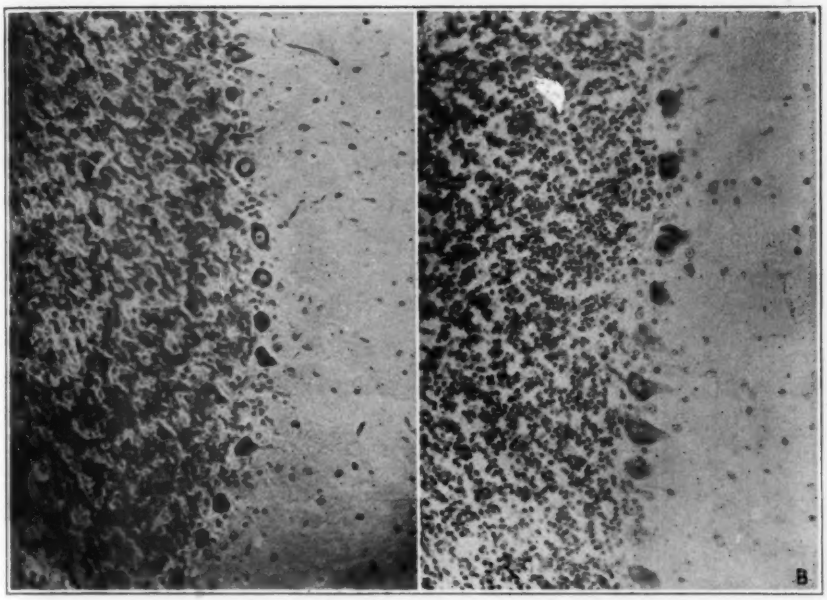

Fig. 1.—Effect of the injection of skatol and indol on the brain cells of a cat; *A*, section of cerebellum of a normal cat; *B*, section of cerebellum of a cat after repeated injections of skatol and indol (reduced from photomicrographs × 310).

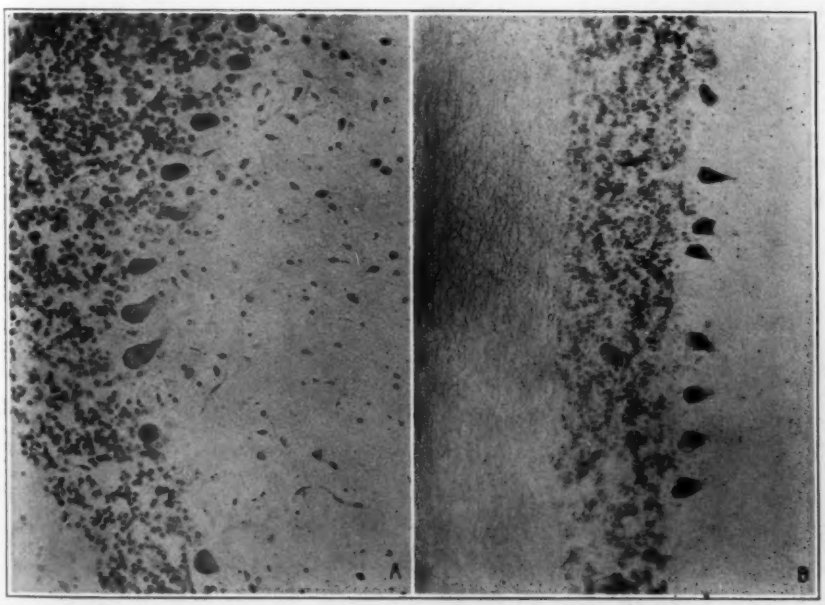

Fig. 2.—The effect on the brain cells of the injection of peptone; *A*, section of cerebellum of a normal dog; *B*, section of cerebellum of a dog that had received an injection of peptone (reduced from photomicrographs × 310).

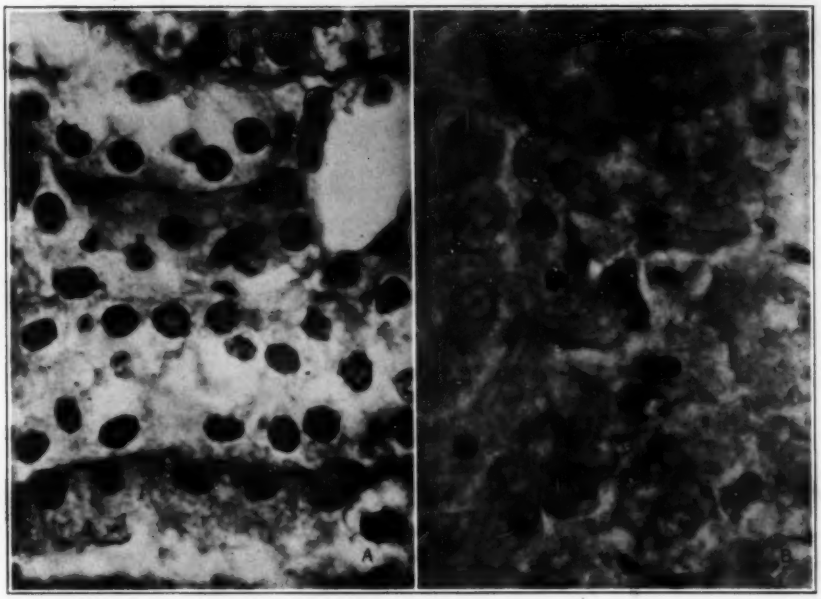

Fig. 3.—Histologic effect on the liver of the injection of peptone; *A*, section of liver of a normal dog; *B*, section of liver of a dog that had received an injection of peptone (reduced from photomicrographs × 1640).

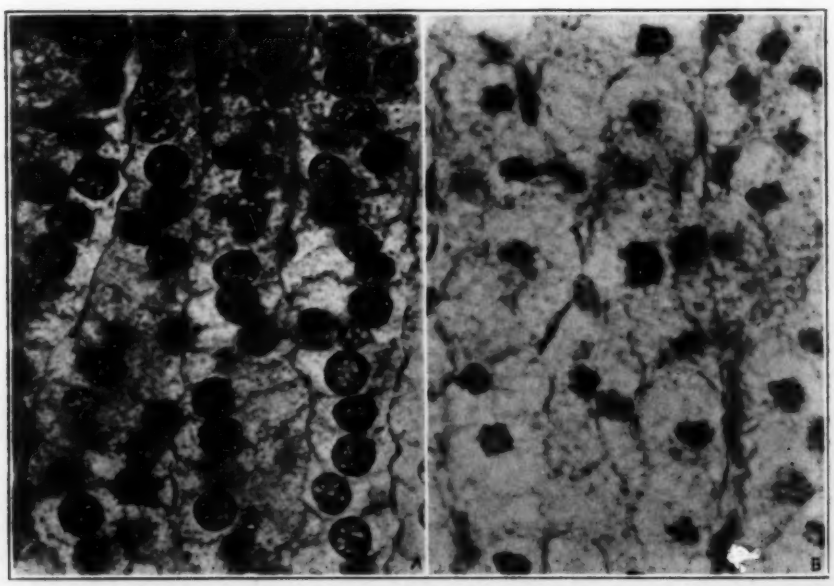

Fig. 4.—Histologic effect on the suprarenals of the injection of peptone; *A*, section of suprarenal of a normal dog; *B*, section of suprarenal of a dog that had received an injection of peptone; (reduced from photomicrographs × 1640).

TABLE 1.—*Histologic Effects of the Injection of Skatol and of Indol**

Exper	Protocols	Cerebrum	Cerebellum	Spinal Cord	Liver	Suprarenals
1	Cat: ether anesthesia; 30 c.c. skatol solution intravenously at intervals of 8 minutes and 27 minutes; killed 7 days later	No hyperchromatic cells; all fatigued or exhausted	No hyperchromatic cells; an occasional active cell; nearly all markedly fatigued; some exhausted	All cells fatigued; granules small and not deeply stained	Loss of cytoplasm in all cells; very large vacuoles in peripheral cells of lobule	Cells in outer half of cortex large, pale, and vacuolated with eccentric nuclei; medulla not examined
2	Cat: weight, 2.528 kg.; on each of 11 successive days, subcutaneous injections of skatol or indol as follows: skatol, 1 c.c.; 1 c.c.; 1 c.c.; 1 c.c.; indol, 1 c.c.; 2 c.c.; skatol, 2 c.c.; 2 c.c.; indol, 2 c.c.; skatol, 2 c.c.; indol, 6 c.c.; killed 5 hours after last dose	An occasional active cell; almost all cells fatigued; some exhausted	An occasional active cell; almost all cells fatigued; some exhausted	Anterior horn cells active	No loss of cytoplasm or vacuolation; congestion of blood vessels; many leukocytes	Cells in outer quarter of cortex; loss of cytoplasm and greatly vacuolated; medulla pale; cells show loss of cytoplasm; sinuses not distended
3	Cat: weight, 1.918 kg.; on each of 10 successive days, subcutaneous injections of skatol or indol as follows: skatol, 1 c.c.; 1 c.c.; 1 c.c.; indol, 1½ c.c.; 2 c.c.; skatol, 2 c.c. a.m.; 5 c.c. p.m.; indol, 2 c.c.; omitted one day; indol, 6 c.c.; killed 5 hours after last dose	Nearly all fatigued; a few exhausted	Some hyperchromatic cells; many fatigued; a few exhausted	Anterior and posterior horn cells nearly all active; a few fatigued	No loss of cytoplasm nor vacuolation; a slightly diffuse stain; no nucleolar change	Very marked loss of cytoplasm and vacuolation in outer half of cortex; medulla pale, but no loss of cytoplasm nor vacuolation
4	Cat: weight, 1.665 kg.; on each of 8 successive days, subcutaneous injections of skatol or indol as follows: skatol, 1 c.c.; indol, 2 c.c.; 2 c.c.; skatol, 2 c.c.; 2 c.c.; indol, 2 c.c.; skatol, 2 c.c.; indol, 6 c.c.; killed 5 hours after last dose	A few hyperchromatic and active cells; some fatigued; a few exhausted	No hyperchromatic cells, many active; some fatigued; none exhausted	All cells hyperchromatic or active	Very slight loss of cytoplasm, if any; no vacuolation or nucleolar change; does not stain sharply	Great loss of cytoplasm and vacuolation in outer two thirds of cortex
5	Cat: weight, 1.788 kg.; on each of 8 successive days, subcutaneous injections of skatol or indol as follows: skatol, 1 c.c.; indol, 2 c.c.; 2 c.c.; skatol, 2 c.c.; 2 c.c.; indol, 2 c.c.; skatol, 2 c.c.; indol, 4 c.c.; died approximately 24 hours after last dose	An occasional active cell; nearly all cells badly fatigued	An occasional active cell; nearly all cells badly fatigued	All cells show marked loss of cytoplasm	Congested; no loss of cytoplasm; diffuse stain; nuclei central and distinct but vary much in size	Marked loss of cytoplasm throughout cortex; greatest loss in central part where it is total in some cells; medulla normal
6	Cat: weight, 1.738 kg.; on each of 8 successive days, subcutaneous injections of skatol or indol as follows: skatol, 1 c.c.; indol, 2 c.c.; 2 c.c.; skatol, 2 c.c.; 2 c.c.; indol, 2 c.c.; skatol, 4 c.c.; indol, 6 c.c.; killed 4½ hours after last injection	Marked chromatolysis; no hyperchromatic cells; some exhausted	All cells fatigued; all nucleoli intact	.....	Slight loss of cytoplasm in some cells; no marked vacuolation; general appearance of degeneration	Loss of cytoplasm in outer half of cortex with complete loss in only a few; medulla pale, not congested

* Saturated solutions of skatol and of indol in 0.85 per cent. sodium chlorid used throughout. Experiments by Dr. F. W. Hitchings and Amy F. Rowland; histologic examinations by Dr. J. B. Austin.

TABLE 2.—*Histologic Effects of the Injection of Leucin**

Exper.	Protocols	Cerebrum	Cerebellum	Spinal Cord	Liver	Suprarenals
1	Cat: weight, 2.606 kg.; on each of 8 successive days subcutaneous injections of leucin as follows: 2 c.c.; 2 c.c.; 2 c.c.; 4 c.c.; 2 c.c.; 4 c.c.; 4 c.c.; 4 c.c.; killed 6½ hours after last injection	An occasional hyperchromatic and active cell; many fatigued cells and some exhausted; more cells fatigued than in cerebellum	An occasional hyperchromatic and active cell; many fatigued cells and some exhausted	Cells of anterior horn active; others fatigued	Well stained with sharply defined granules; no loss of cytoplasm; no vacuolation or cellular change	Cells of outer third of cortex vacuolated and enlarged, with marked loss of cytoplasm; medulla well stained and normal
2	Cat: weight, 2.899 kg.; on each of 6 successive days subcutaneous injections of leucin as follows: 2 c.c.; 4 c.c.; 2 c.c.; 4 c.c.; 4 c.c.; 6 c.c.; killed 5¼ hours after last injection	A few hyperchromatic and active cells; nearly all fatigued; some exhausted	Some hyperchromatic and active cells; many fatigued and some exhausted	All cells fatigued.....	Uniformly slight loss of cytoplasm with small vacuoles in some cells	Cells of outer half of cortex show very great loss of cytoplasm and vacuolation with increase in size; medulla pale, not congested
3	Cat: weight, 2.310 kg.; on each of 6 successive days subcutaneous injections of leucin as follows: 2 c.c.; 4 c.c.; 2 c.c.; 4 c.c.; 4 c.c.; 6 c.c.; killed 5 hours after last injection	Some hyperchromatic and active cells; nearly all cells fatigued; a few exhausted	An occasional hyperchromatic and active cell; nearly all cells fatigued; a few exhausted	All cells hyperchromatic or active	Loss of chromatin in all cells; with vacuolation in some; most marked changes in periphery of lobule	Loss of cytoplasm in varying degrees in outer third of cortex; cells in this area greatly increased in size; medulla normal
4	Cat: weight, 1.638 kg.; on each of 5 successive days subcutaneous injections of leucin as follows: 3 c.c.; 2 c.c.; 4 c.c.; 4 c.c.; 6 c.c.; killed 5 hours after last dose	No active cells; all fatigued	An occasional active cell; nearly all cells fatigued; some exhausted	No active cells; all fatigued	Slight uniform loss of cytoplasm throughout; no vacuolation	All cells of cortex, except a thin layer around medulla, show great loss of cytoplasm with vacuoles in some cells

* One per cent. solution of leucin in 0.85 per cent. sodium chlorid used throughout. Experiments by A. F. Rowland; histologic examinations by Dr. J. B. Austin.

TABLE 3.—*Histologic Effects of the Injection of Peptone**

Exper.	Protocols	Cerebrum	Cerebellum	Spinal Cord	Liver	Suprarenals
1	Dog: weight, 3.050 kg.; ether; 10 c.c. peptone solution injected in femoral vein; died 4 hours later; sections taken immediately	Many hyperchromatic cells; the majority fatigued; some exhausted	Many hyperchromatic cells; some fatigued and exhausted	.....	All cells vacuolated, nuclei normal; no congestion of capillaries	Loss of cytoplasm, principally in cells of cortex
2	Dog: Ether; 10 c.c. peptone solution injected in femoral vein; killed 36 minutes later	Nearly all cells fatigued	Nearly all cells fatigued	Cervical cord; all large cells hyperchromatic	.....	Normal; no vacuolation or especial loss of cytoplasm from either cortex or medulla

* An 8 per cent. solution of Witte's peptone in 0.85 per cent. sodium chlorid used throughout. Experiments by Dr. F. W. Hitchings; histologic examinations by Dr. J. B. Austin.

B. Physicochemical and Functional Studies

Measurements of the Suprarenal Output

Feces Extract: Indol and Skatol.—Seven tests of the suprarenal output were made by Cannon's method after the injection of feces extract; three, after the injection of skatol, and two, after the injection of indol.

Table 4.—*Histologic Effects of Toxic Products of Intestinal Obstruction on the Central Nervous System**

Exper.	Protocols	Cerebrum	Cerebellum	Spinal Cord
1	Dog: ether-morphin; weight, 30 kg.; 15 c.c. intestinal extract from obstructed loop of intestine of another dog injected after overtransfusion; killed 7½ hours after injection	Most cells fatigued; nuclear membranes of most cells intact, and nucleoli well stained; some exhausted cells, many on borderline between fatigue and exhaustion, with complete loss of chromatin except in nucleolus	Cells in every stage of fatigue and exhaustion; differential Purkinje's cell count: active, 35 per cent.; fatigued, 51 per cent.; exhausted, 14 per cent.	Marked loss of chromatin from many cells of anterior horn; no completely exhausted cells, but many fatigued; small cells of posterior horn similarly affected
2	Dog: ether-morphin; 30 c.c. intestinal extract from obstructed loop of intestine of another dog injected after transfusion; killed 18 hours after injection	No hyperchromatic cells; many fatigued, a few exhausted, in many of last nuclei are enlarged	No hyperchromatic cells; many fatigued, a few in various stages of exhaustion; nucleoli of most cells well stained; differential Purkinje's cell count: active, 45 per cent.; fatigued, 42 per cent.; exhausted, 13 per cent.	
3	Dog: ether-morphin; weight, 16 kg.; 15 c.c. of intestinal extract from obstructed loop of intestine of another dog; transfused 13 hours later; died 7 hours after transfusion, 20 hours after injection	All cells in state of extreme fatigue or exhaustion; most of nuclei and nucleoli affected, many of them disintegrated	Differential Purkinje's cell count: active, 40 per cent.; fatigued, 35 per cent.; exhausted, 25 per cent.	Anterior horn: cells very little affected. Posterior horn: cells show great loss of chromatin and enlarged nuclei
4	Dog: ether-morphin; weight, 13 kg.; injection, 15 c.c. of intestinal extract from obstructed loop of intestine of another dog; transfused 14 hours later; died 5½ hours after transfusion, 19½ hours after injection	A very few hyperchromatic cells; others in all stages of fatigue and exhaustion; greater loss of chromatin than from cells of cerebellum	Cells in all stages; a very few hyperchromatic; differential Purkinje's cell count; active, 45 per cent.; fatigued, 26 per cent.; exhausted, 29 per cent.	Dorsal region: no signs of exhaustion in any cells; some loss of granules in many large cells; nucleoplasmar relation altered and greater loss of granules in smaller cells

* The average differential Purkinje's cell count in normal dogs is added for convenient comparison with the differential counts in the above table: active, 71.2 per cent.; fatigued, 28.1 per cent.; exhausted, 0.7 per cent. Experiments by Dr. F. W. Hitchings and Dr. J. B. Austin.

A positive reaction was secured in every case but one (Table 5, Figs. 5 and 6). The third test made after a portion of the withdrawn sample of blood from the injected animal had been exposed, seemed to indicate that a longer period was required for oxidation of the epinephrin content of the blood than that required in our other studies.

In three experiments, feces extract was injected in animals after the removal of both suprarenals, and Cannon's test applied with the uniformly negative findings shown in Table 6.

Leucin.—Two tests of the suprarenal output by Cannon's method were made after the injection of leucin, with positive findings in each (Table 7).

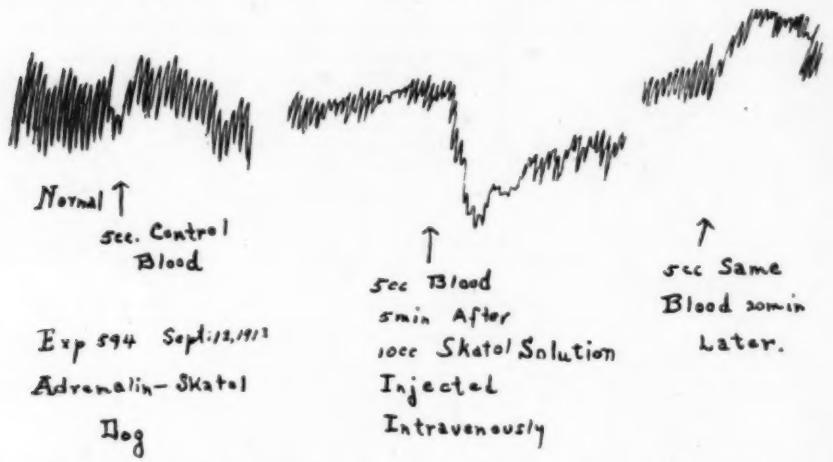

Fig. 5.—Effect on the suprarenal output of the injection of skatol (Cannon's test, positive).

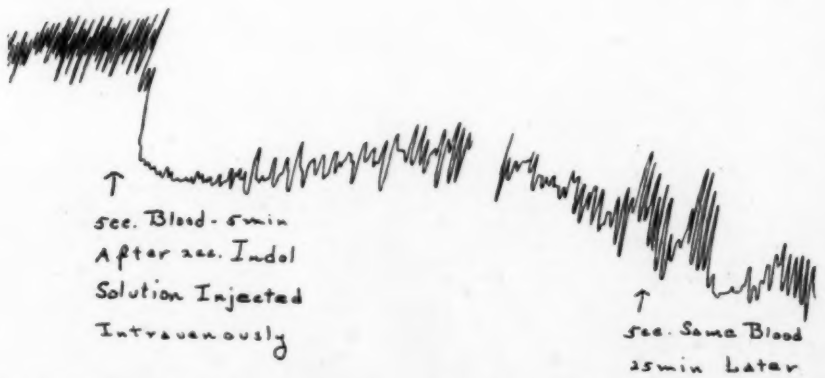

Fig. 6.—Effect on the suprarenal output of the injection of indol (Cannon's test, positive).

Peptone.—Three tests of the suprarenal output by Cannon's method were made after the injection of peptone with positive findings in each (Table 8).

As a corollary to these experiments, two further tests were made, one after the removal of both suprarenals; the other after division of the splanchnic nerves. In each of these animals, Cannon's test after

TABLE 5.—*Effect of Injection of Skatol or Indol on the Suprarenal Output**

Experiment	Animal	Anesthetic	Epinephrin Test 1 (Control) Before Injection	Injection*	Epinephrin Test 2 5 Minutes After Injection	Epinephrin Test 3 Later Test of Sample Used in Test 2
1	Cat	Ether	Negative	1.2 c.c. skatol solution	Negative	Same sample 10 minutes later, negative
2	Cat	Ether	Negative	8 c.c. skatol solution	Positive	Same sample 20 minutes later, positive; same sample 30 minutes later, negative
3	Cat	Ether	Negative	6 c.c. indol solution	Negative	
4	Cat	Ether	Negative	6 c.c. indol solution	Positive	Same sample 10 minutes later, positive; same sample 25 minutes later, negative
5	Dog	Ether	Negative	10 c.c. skatol solution	Positive	Same sample 20 minutes later, negative

* Saturated solutions of skatol or indol in 0.85 per cent. sodium chlorid or cat serum used throughout; all injections intravenous. Experiments by Dr. F. W. Hitchings.

TABLE 6.—*Effect of Intravenous Injection of Feces Extract (2 c.c.) on the Suprarenal Output After Suprarenalectomy (Cannon's Test)**

Experiment	Animal	Anesthetic	Epinephrin Test 1 (Control) After Suprarenalectomy Before Injection	Injection	Epinephrin Test 2
1	Cat	Ether	Negative	24 minutes after double suprarenalectomy	10 minutes after injection; negative
2	Cat	Ether	Negative	12 minutes after double suprarenalectomy	12 minutes after injection; negative
3	Rabbit	Urethan	Negative	15 minutes after double suprarenalectomy	10 minutes after injection; negative

* Experiments by Dr. F. W. Hitchings.

TABLE 7.—*The Effect of the Intravenous Injection of Leucin on the Suprarenal Output (Cannon's Test)**

Experiment	Animal	Anesthetic	Epinephrin Test 1 (Control) Before Injection	Injection	Epinephrin Test 2	Epinephrin Test 3
1	Cat	Ether	Negative	2 c.c. leucin solution	5 minutes after injection; positive	Same sample 30 minutes later, negative
2	Rabbit	Urethan	Negative	2 c.c. leucin solution	5 minutes after injection; positive	Same sample 30 minutes later, negative

* One per cent. solution of leucin in 0.85 per cent. sodium chlorid. Experiments by Dr. F. W. Hitchings.

TABLE 8.—*Effect of Intravenous Injection of Peptone on the Suprarenal Output (Cannon's Test)**

Experiment	Animal	Anesthetic	Epinephrin Test 1 (Control) Before Injection	Injection	Epinephrin Test 2	Epinephrin Test 3
1	Dog	Ether	Negative	10 c.c. peptone solution	5 minutes after injection; positive	Same sample 20 minutes later, negative
2	Cat	Ether	Negative	5 c.c. peptone solution	12 minutes after injection, positive; 28 minutes after injection, positive	First sample 11 minutes later, negative
3	Dog	Ether	Negative	50 c.c. peptone solution	10 minutes after injection; positive	Same sample 20 minutes later, negative

* An 8 per cent. solution of Witte's peptone in 0.85 per cent. sodium chlorid used throughout. Experiments by Dr. F. W. Hitchings.

TABLE 9.—*Effect of Intravenous Injection of Peptone on the Suprarenal Output After Suprarenalectomy or Division of Splanchnic Nerves**

Experiment	Animal	Anesthetic	Epinephrin Test 1 (Control) Before Injection	Injection	Epinephrin Test 2
1	Dog	Ether	Negative	10 c.c. peptone solution 20 minutes after double suprarenalectomy	5 minutes after injection; negative
2	Dog	Ether	Negative	20 c.c. peptone solution 5 minutes after division of splanchnics	5 minutes after injection; negative

* An 8 per cent. solution of Witte's peptone in 0.85 per cent. sodium chlorid used throughout. Experiments by Dr. F. W. Hitchings.

TABLE 10.—*Effect of Intravenous Injection of Peptone on the Suprarenal Output of a Morphinized Animal and on an Animal Anesthetized with Nitrous Oxid**

Experiment	Animal	Anesthetic	Epinephrin Test 1 (Control) Before Injection	Injection	Epinephrin Test 2	Epinephrin Test 3
1	Dog	Ether-morphin	Negative	20 c.c. peptone solution 2 hrs. after administration of morphin, 6 grains	5 minutes after injection, negative; 20 minutes after injection, negative	
2	Dog	Nitrous oxid	Negative	15 c.c. peptone solution 36 minutes after anesthesia started	5 minutes after injection, positive	Same sample 20 minutes later, negative

* An 8 per cent. solution of Witte's peptone in 0.85 per cent. sodium chlorid used throughout. Experiments by Dr. F. W. Hitchings.

the injection of peptone was negative (Table 9, Fig. 7). One test of the suprarenal output after the injection of peptone in a morphinized animal was negative; in an animal anesthetized with nitrous oxid the test was positive (Table 10).

In three animals, the suprarenal activity after the injection of peptone was tested by Elliott's method. Cats were used in these experiments, in each of which a left suprarenal neurectomy was performed from fourteen to sixteen days before the injection of the peptone. After the injection of from 7 to 10 c.c. of the peptone solution, the suprarenals were removed, and the epinephrin content tested by Elliott's method. In each of these animals, the epinephrin content of the left suprarenal, the one protected by the previous neurectomy, was greater than the epinephrin content of the right suprarenal (Fig. 8). The injection and operative procedures on these animals were accomplished under nitrous oxid anesthesia.

TABLE 11.—*The Effect of the Injection of Skatol and Indol on the Chemical Content of Certain Organs and Tissues**

	Thyroid: Iodin Content, per Cent.	Suprarenals		Liver: Glycogen Content, per Cent.	Muscle: Glycogen Content, per Cent.	Hypophysis: Pituitary Activity, per Cent.
		Epinephrin Content, per Cent.	Epinephrin Activity, per Cent.			
Normal cats...	0.0156	0.1	5 (of standard)	0.508	0.56	25 (of standard)
Injected cats..	0.0189	0.1	5 (of standard)	1.08	Trace	10 (of standard)

* Experiments by Amy F. Rowland; assays by a commercial laboratory. Saturated solutions of skatol and indol in 0.85 per cent. solution sodium chlorid used throughout.

Summary of Functional Studies of the Suprarenals.—In each type of autointoxication studied, the activation of the animal by the toxic agent produced an increased activity of the suprarenals, which was manifested by an increased output of epinephrin.

Measurements of the Chemical Content of Various Organs and Tissues.—Assays of the iodin content of the thyroid; of the epinephrin content of the suprarenals and the epinephrin activity; of the glycogen content of the liver and of the voluntary muscle, and of the pituitary activity were made for the author in three series of eight animals each, which had been subjected respectively (*1*) to injections of skatol or indol; (*2*) to injections of leucin, and (*3*) to injections of peptone. In each case, the injections were given daily for from four to ten days. The chemical findings are given in Tables 11 to 13.

In no instance was the epinephrin content or the epinephrin activity altered; the iodin content of the thyroid was increased in the animals that received leucin or skatol and indol, but decreased in those that received peptone; the glycogen content of voluntary muscle was decreased

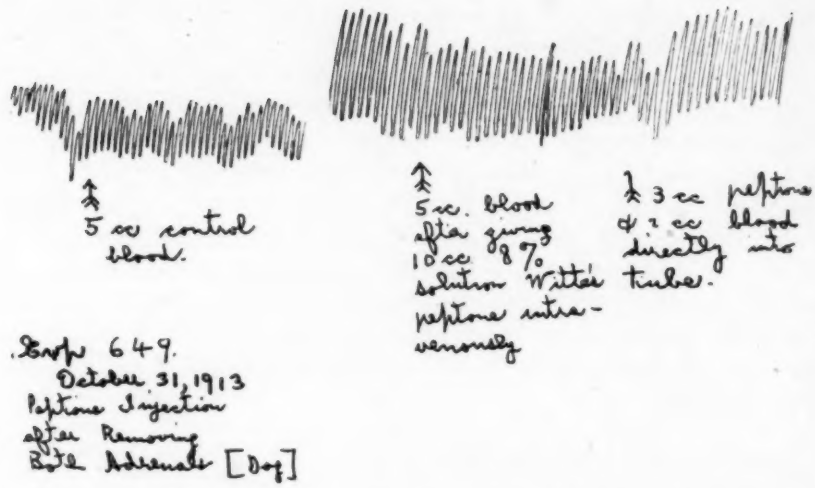
5 cc control blood.
5 cc. blood after giving 10 cc 8% solution Witte's peptone intravenously
½ 3 cc peptone & ½ cc blood directly into tube.
Exp. 649.
October 31, 1913
Peptone Injection after Removing Both Adrenals [Dog]

Fig. 7.—Effect on the suprarenal output of the injection of peptone in a dog after the removal of both suprarenals (Cannon's test, negative).

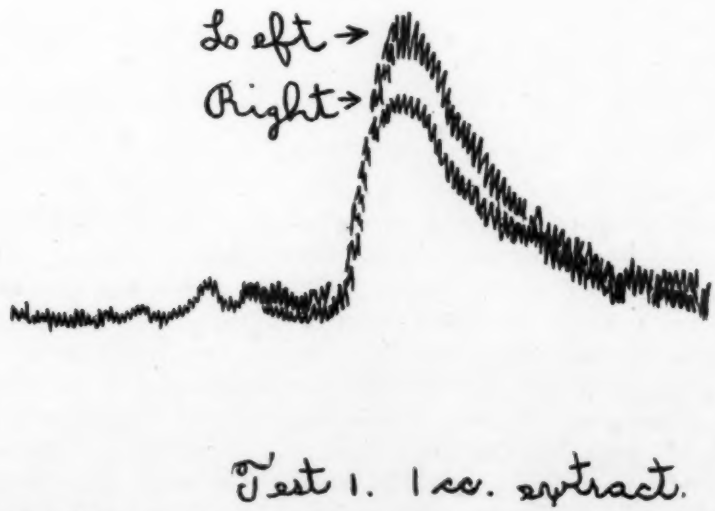

Fig. 8.—Effect on the suprarenal output of the injection of peptone. (Elliott's test); the greater rise of blood pressure resulting from the injection of an extract of the left suprarenal is noted.

TABLE 12.—*Effect of the Injection of Leucin on the Chemical Content of Certain Organs and Tissues**

	Thyroid: Iodin Content, per Cent.	Suprarenals		Liver: Glycogen Content, per Cent.	Muscle: Glycogen Content, per Cent.	Hypophysis: Pituitary Activity, per Cent.
		Epinephrin Content, per Cent.	Epinephrin Activity, per Cent.			
Normal cats....	0.0156	0.1	5 (of standard)	0.508	0.56	25 (of standard)
Cats, after injection of leucin	0.0187	0.1	5 (of standard)	0.44	Trace	20 (of standard)

* A 1 per cent. solution of leucin in 0.85 per cent. sodium chlorid used throughout. Experiments by Amy F. Rowland; assays by a commercial laboratory.

TABLE 13.—*The Effect of the Injection of Peptone on the Chemical Content of Certain Organs and Tissues**

	Thyroid: Iodin Content, per Cent.	Suprarenals		Liver: Glycogen Content, per Cent.	Muscle: Glycogen Content, per Cent.	Hypophysis: Pituitary Activity, per Cent.
		Epinephrin Content, per Cent.	Epinephrin Activity, per Cent.			
Normal cats....	0.0156	0.1	5 (of standard)	0.508	0.56	25 (of standard)
Cats, after injection of peptone	0.0049	0.1	5 (of standard)	0.305	0.48	10 (of standard)

* Experiments by Amy F. Rowland; assays by a commercial laboratory. An 8 per cent. solution of Witte's peptone in 0.85 per cent. sodium chlorid used throughout.

TABLE 14.—*Effect of Autointoxication Upon the Weights of Individual Animals After Stated Number of Daily Injections**

Skatol and indol					Leucin					Peptone				
		Weight					Weight					Weight		
Animal	No. of Days	Before Injections, Kg.	After Injections, Kg.	Loss,† per Cent.	Animal	No. of Days	Before Injections, Kg.	After Injections, Kg.	Loss,‡ per Cent.	Animal	No. of Days	Before Injections, Kg.	After Injections, Kg.	Loss,§ per Cent.
1	11	2.528	1.918	24	1	8	2.608	2.183	16	1	21	2.138	1.173	45
2	11	2.268	1.825	19	2	9	3.228	2.588	19	2	16	2.568	2.413	6
3	11	1.918	1.438	25	3	9	3.438	2.810	20	3	16	2.308	1.898	17
4	8	1.665	1.458	12	4	9	3.453	2.890	16	4	16	1.818	1.433	21
5	8	1.788	1.313	26	5	9	4.078	3.538	13	5	16	2.288	1.918	16
6	10	2.678	2.443	8	6	7	2.899	2.423	16	6	15	3.288	2.438	26
7	6	1.018	0.830	17	7	7	2.310	2.163	6	7	8	2.666	1.328	50
8	8	2.838	2.618	7	8	5	3.238	2.825	12	8	8	2.156	1.993	7
9	8	3.083	2.398	22	9	6	2.648	2.473	6					
10	5	3.458	3.288	5	10	5	1.638	1.453	11					
11	5	1.938	1.768	8	11	5	2.738	2.473	9					
12	5	2.288	2.118	7	12	5	2.413	2.213	8					
13	8	1.738	1.958	12 (gain)	13	5	3.828	3.428	10					
14	4	2.318	2.338	0.8 (gain)										

* Experiments by Miss A. F. Rowland.
† Average daily loss 1.55 per cent.
‡ Average daily loss 1.82 per cent.
§ Average daily loss 1.62 per cent.

in each instance, but the glycogen content of the liver was markedly increased in the animals receiving skatol and indol; the pituitary activity was decreased in every instance.

C. Clinical Observations

The general clinical aspect of the animals in the various series of experiments given in the foregoing description did not vary with the type of intoxication. In each, the general symptoms were essentially the same, increasing in severity with the degree of intoxication.

Observations of the blood pressure after the injection of peptone and after the injection of extract made from an isolated loop of intestine, showed a decided fall in each instance (Figs 9 and 10).

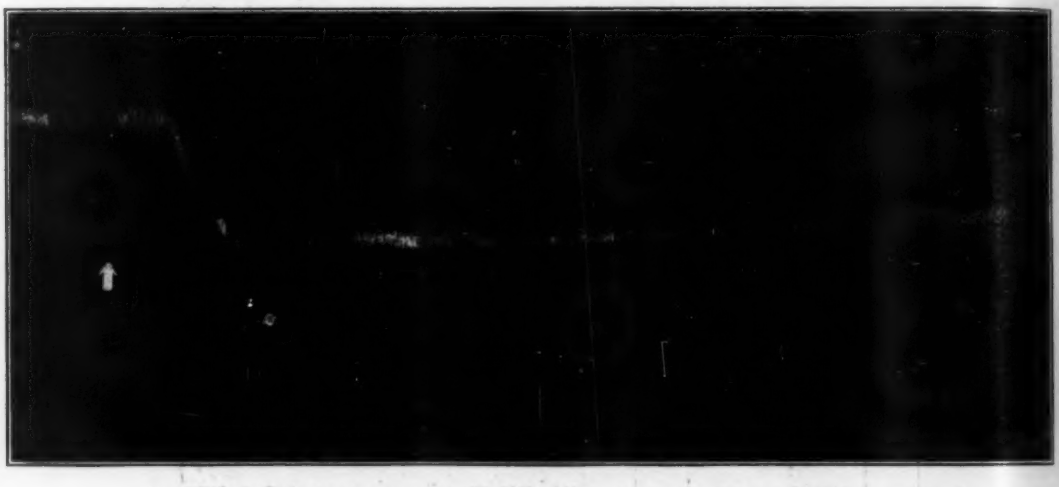

Fig. 9.—Effect on the blood pressure of the injection of peptone; arrow indicates the injection of Witte's Peptone (8 per cent. solution in 0.9 per cent. sodium chlorid) into the femoral artery.

No significant change in temperature or pulse was noted, except a marked drop of both in animals that were in an advanced stage of exhaustion after the repeated administration of the intoxicating agent for several consecutive days.

Every animal, except two that received daily doses of skatol or indol, lost weight, the average daily loss as shown by Table 14 being 1.55 per cent. in the animals that received skatol and indol; 1.82 per cent. in those receiving leucin, and 1.62 per cent. in those receiving peptone. The greatest loss of weight in individual animals was observed in the last named group.

The lowered blood pressure, loss of weight, increasing lassitude, indifference to surroundings, all the signs of a general exhaustion, are

identical with the symptoms observed in the clinic in patients suffering from autointoxication caused by the presence of any of the products allied to those utilized in these studies.

The clinical effects of intestinal obstruction are given in detail in the previous publication already cited, where it is noted that the symptoms of collapse were practically always severe, and were followed (or accompanied) by either a rise or a fall of temperature. In human patients with intestinal obstruction, it is constantly noted that the clinical symptoms are largely cerebral. The patient is usually free from pain, but becomes restless, delirious and unconscious. The pulse and respiration

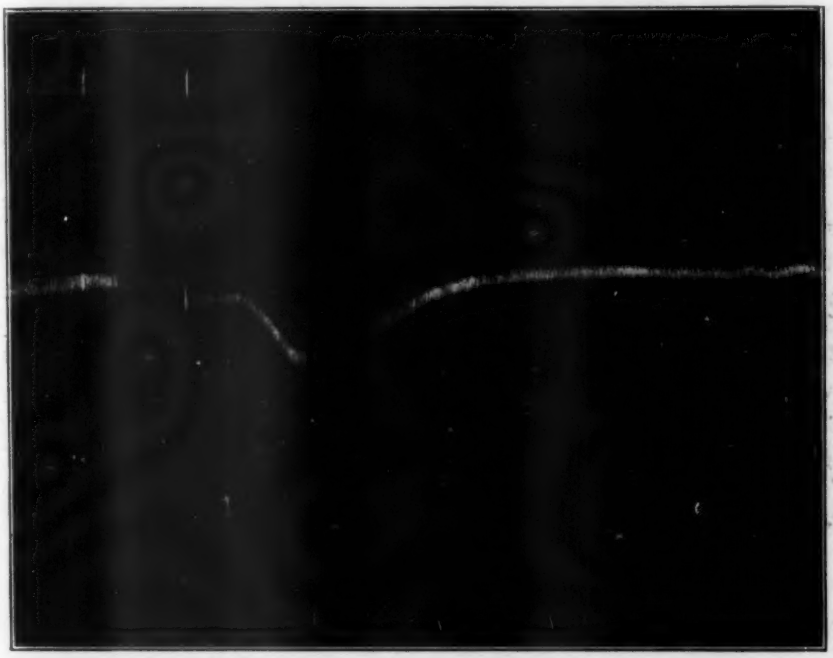

Fig. 10.—Effect on the blood pressure of the injection of intestinal extract from an isolated loop of intestine; markers indicate a period of thirty seconds, and the arrow indicates the injection of toxin in the external jugular.

become rapid, while the temperature may be either high or subnormal. These clinical findings are in accord with the histologic picture, which shows that the principal lesion is in the brain.

General Summary

1. The introduction of toxic agents identical with certain of the end-products of intestinal digestion, with an end-product of protein metabolism, and with a product of arrested protein catabolism as well as the

toxins which become active in acute intestinal obstruction caused phenomena identical with those observed in the clinic in cases of autointoxication from like causes.

2. The histologic changes in the central nervous system produced by the injection of feces extract, of skatol or indol, of leucin, of peptone, and of the products of intestinal obstruction, were identical with those which followed the application of other exhaustion-producing agents; i. e., early hyperchromatism, followed by progressive changes to the state of exhaustion.

3. Histologic changes identical with those found in other studies of exhaustion were found in the liver and in the suprarenals after the injection of leucin and of peptone, the changes in the suprarenals being most marked in the cortex, with the exception that but little change in the liver was observed after the injection of skatol and indol.

4. Except in the presence of morphin, the epinephrin output was markedly increased by the injection of each of the agents employed in this group of studies.

5. The iodin content of the thyroid gland was increased in the animals that received indol and skatol or leucin; but was decreased in those receiving peptone.

6. The glycogen content of the liver decreased in the animals receiving leucin or peptone, but increased in those receiving indol and skatol. This is in accord with the histologic picture. The glycogen content of voluntary muscle was increased in each animal subjected to any of the toxic agents studied.

7. The pituitary activity was decreased in the presence of each of the toxic agents studied; the epinephrin content and epinephrin activity were unaltered.

8. These studies make it appear that the primary cause of exhaustion from autointoxication is identical with that of exhaustion from other causes; i. e., the primary cause of the general exhaustion of the organism in autointoxication is exhaustion of the central nervous system, especially the brain.

MALIGNANT TUMORS OF THE THYMUS*

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The mediastinum contains a number of important structures which bear a close relationship to each other in this confined space. A tumor of the mediastinum, whether benign or malignant, is a serious matter. Comparatively small benign tumors may cause very severe symptoms. Malignant tumors of thymic origin, although uncommon, occur frequently enough to be of clinical importance.

Thymic neoplasms are difficult to interpret and to classify. The histogenesis of the thymus, especially the origin of the small lymphoid cells, which compose the larger part of the organ, is not clear. The work of Hammar[1] and Maximow,[2] however, seems to demonstrate that these cells are true lymphocytes. This conclusion is confirmed by the more recent work of Badertscher.[3] According to certain investigators (Stöhr,[4] and Papenheimer[5]) the lymphoid cells are epithelial in origin. It is generally agreed that the cells which form the corpuscles of Hassall are of entodermal origin. The thymus, being composed of both mesodermal and entodermal elements, may give rise to sarcomas, carcinomas or mixed tumors (carcinosarcomas), according to the element or elements involved in the neoplastic growth.

REPORT OF CASES

CASE 1[6]—*History and Course.*—A woman, white, aged 19, entered the University of Virginia Hospital complaining of a swelling of the neck, dyspnea and dysphagia. There was edema of the feet and ankles. The patient had had a cough for some time, which was worse at night. Examination revealed a large, hard mass on the left side of the neck, extending from the clavicle to within a short distance of the posterior angle of the jaw. The veins over the tumor and upper thorax were dilated and tortuous. There was a slight degree of exophthalmus. A diagnosis of intrathoracic tumor and tumor of the neck, possibly a combination of Hodgkin's disease with exophthalmic goiter, was made. The patient died, Feb. 12, 1916, with symptoms of asphyxia.

Necropsy.—On removal of the sternum, a hard mass was found occupying

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1. Hammar: Ergebn. d. Anat. u. Entwicklngsgesch. **19**, 1910.
2. Maximow: Arch. f. mikr. Anat. **74**:525, 1909.
3. Badertscher: Am. J. Anat. **17**:437, 1915.
4. Stöhr: Anat. Hefte. **31**:409, 1906.
5. Papenheimer: J. Med. Res. **22**:1, 1910.
6. A report of this case was read by Dr. Harry T. Marshall at the sixteenth annual meeting of the American Association of Pathologists and Bacteriologists, Washington, D. C., May 9, 1916.

the anterior mediastinum. This mass reached from the clavicle to within about 5 cm. of the diaphragm and extended 9 cm. to the right and 5 cm. to the left of the midline. The neoplasm was closely attached to the sternum, adjacent cartilages, ribs and left clavicle by dense fibrous adhesions. The entire tumor occupied the region from the lower end of the thyroid to the pericardium, and extended posteriorly, surrounding the arch of the aorta, adjacent vessels, trachea and bronchi. The esophagus and bronchial lymph nodes were not involved in the tumor. A gross sagittal section of the tumor showed a nodular, granular, whitish gray growth. The pericardium was displaced downward and lay

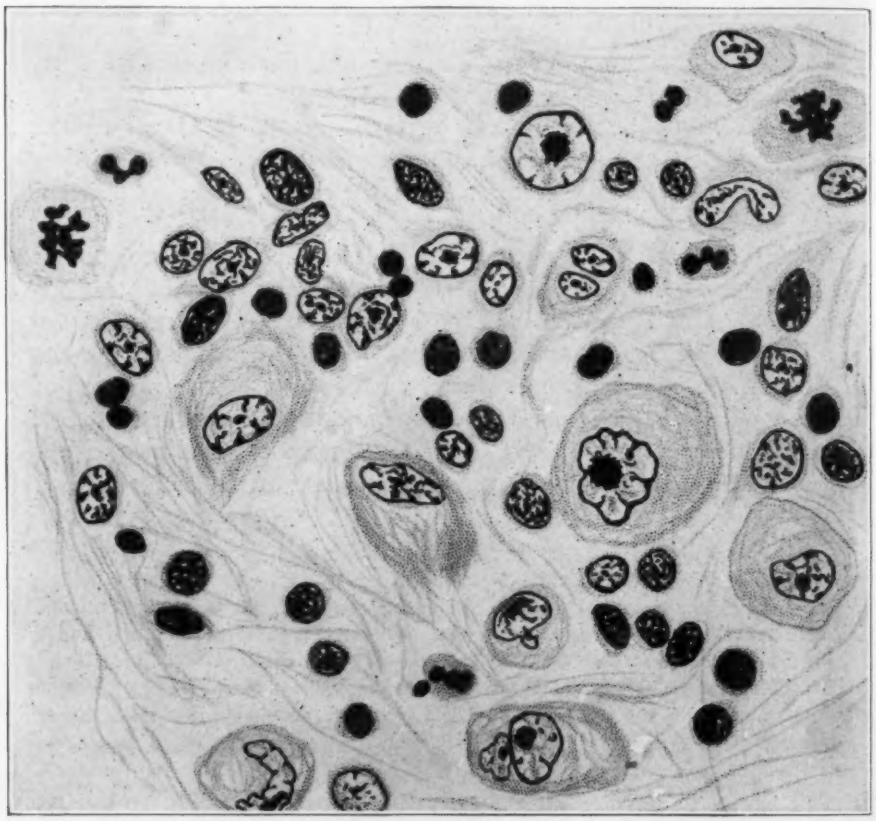

Fig. 1 (Case 1).—Microscopic section of a portion of a thymic tumor. There are a number of large reticular and giant cells in the field. There occur also a number of cells which have large vesicular nuclei and a scanty amount of cytoplasm. Two of these cells are undergoing mitosis. Many small lymphoid cells are also present (× 2,000).

transversely. The pericardial cavity contained about 1,000 c.c. of a dark fluid. The neoplasm, which had invaded the pericardium, was a cauliflower growth. A small tumorous nodule was found on the right auricle.

The right pleural cavity contained 500 c.c. of clear fluid. The left lung was firmly bound to the posterior chest wall by adhesions, and the left pleural cavity contained about 300 c.c. of fluid. There were nodules of metastatic

growth in the left pleura. The left lung showed areas of bronchopneumonia. The kidneys contained neoplastic metastases, and the thyroid showed the picture of a colloid goiter.

Microscopic Examination.—This revealed a confusing picture (Fig. 1). There were three principal types of cells present. The first type was a small round cell with a deeply staining nucleus and little cytoplasm. This cell was indistinguishable from a small lymphocyte. A second type of cell had a large vesicular nucleus with a small amount of cytoplasm. This cell was from two to three times as large as the small lymphoid cells. A number of cells of this type were seen in stages of mitotic division. The third type of cell was very

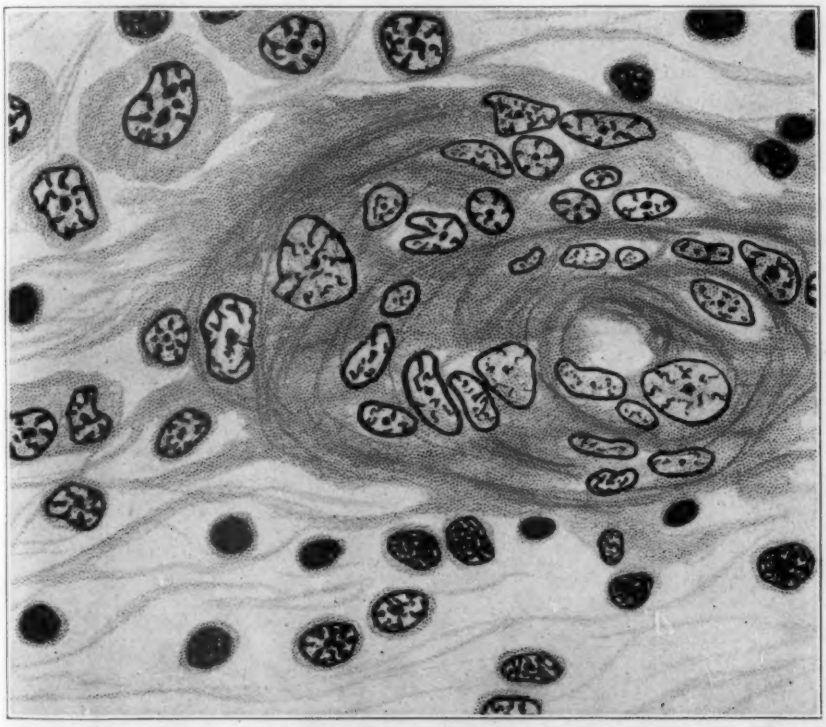

Fig. 2 (Case 1).—Microscopic section of portion of the neoplasm. A group of cells concentrically arranged occupies the center of the field. This body resembles a Hassall's corpuscle. A number of epithelioid and lymphoid cells surround this mass (× 2,000).

large and had an abundant cytoplasm. The nucleus was large and vesicular. When a single nucleus was present, it was usually situated eccentrically. The nuclei were lobulated or multiple. In some fields, concentric cell masses were seen. The masses were hyalinized and the cell borders were not distinct. These structures resembled Hassall's corpuscles (Fig. 2). Scattered throughout the tumor were a number of eosinophilic granulocytes and plasma cells. The stroma in most parts of the tumor was scanty and was composed of fine reticular fibers. In some fields, it was increased in quantity and appeared in heavy, irregular,

hyalinized cords. Connective tissue cells were rarely seen. Thin walled congested capillaries were numerous throughout the tumor.

Case 2.—*History and Course.*—A man, white, aged 25, who entered the University of Virginia Hospital, Sept. 20, 1919, five weeks prior to admission began to suffer from stiffness and soreness of the neck, and about a week later noticed that his neck was enlarged. At the same time, he began to have a choking sensation accompanied by dysphagia. He died, September 24, with

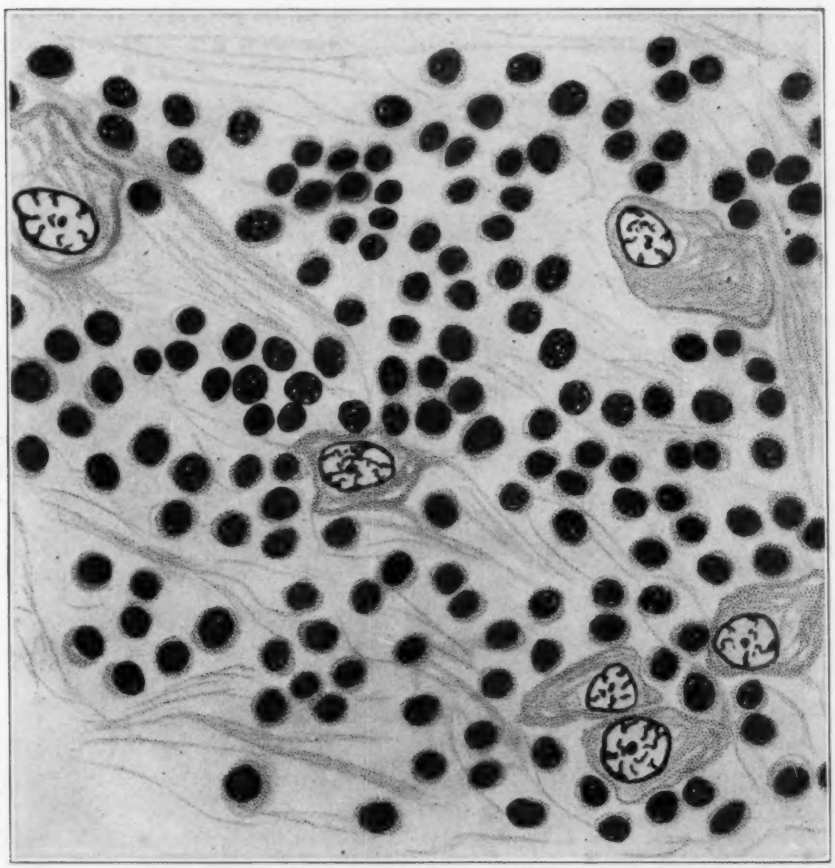

Fig. 3 (Case 2).—Microscopic section of portion of a thymic tumor. Reticular and lymphoid cells are present in the field. The small lymphoid cells greatly outnumber the other types (× 1,500).

symptoms of asphyxia. Examination showed the patient to be a well nourished young man with a pronounced enlargement in the region of the thyroid. This mass was very firm and fixed. There was no glandular enlargement. Mediastinal dulness was somewhat increased in breadth. The examination was otherwise negative.

Necropsy.—The abdominal cavity and viscera appeared normal. On opening the thoracic cavity, a dense mass was encountered in the anterior medi-

astinum, which completely hid the heart. The tumor was firmly adherent to the sternum and had eroded it. Over the surface of the neoplasm there were small areas of necrosis. The mass extended from the lower border of the thyroid cartilage to the diaphram. The cervical portion of the tumor covered the thyroid gland. The trachea was found to be constricted and flattened. The point of greatest compression was just above the bifurcation. The mucous membrane here was slightly hemorrhagic. The pulmonary arteries and veins were also compressed by the mass. The tumor was very firm and hard, being almost the consistency of cartilage. A sagittal section through the tumor showed that it was composed of a white glistening tissue. Lungs, liver and

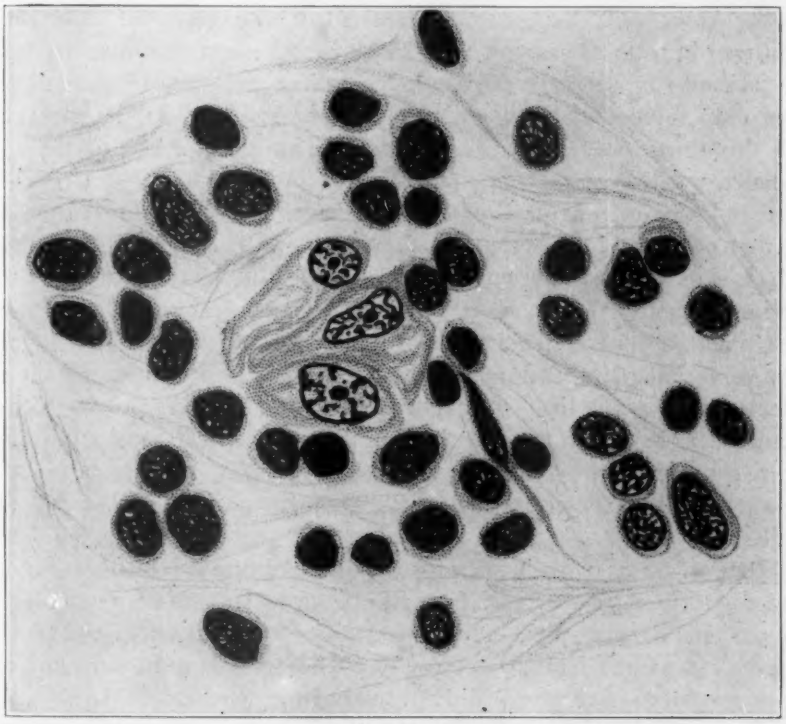

Fig. 4 (Case 2).—Section of the neoplasm. A group of large reticular cells occupy the center of the field. This cluster of cells is surrounded by cells of the small lymphocyte type (× 2,000).

spleen showed marked congestion. Metastatic nodules of tumor tissue were found in the kidneys.

Microscopic Examination.—The predominant type of cells of which the tumor was composed resembled a small lymphocyte (Fig. 3). These cells had small densely staining nuclei and scanty cytoplasm. A second type of cell, with a large vesicular nucleus and a small amount of cytoplasm, was present in much smaller numbers than were the small lymphoid cells. A few larger cells with abundant cytoplasm and large vesicular nuclei were also seen. The nuclei of this third type of cell were lobulated or multiple. These large cells were sometimes seen in clusters (Fig. 4). The stroma was composed of fine reticular

fibers, and connective tissue cells were rarely seen. Throughout the stroma were a number of thin-walled congested capillaries. The tumor cells were grouped into nodules by heavy bands of connective tissue.

REVIEW OF LITERATURE

Rubaschow [7] was able to collect from the literature sixty-nine cases reported as tumors of thymic origin. He questions the origin of some of the cases of this series. Fifty-two of the tumors were described as sarcoma, and twelve as carcinomas. Lymphosarcoma occurred in nineteen of a series of thirty-three cases of thymic sarcomas which Rubaschow considered authentic. Eighteen of the cases of this series occurred in patients younger than 25 years and twenty-six cases occurred in patients younger than 40 years. Symmers and Vance [8] were able to find only three cases of thymic epithelioma recorded in the literature. To this series they add a fourth case. The average age of the four patients was 57 years.

Clinically, the picture produced by tumors of the thymus is the same as that produced by other mediastinal tumors. Dyspnea and dysphagia are among the earliest symptoms. Cough and hoarseness are often present. Pain and cyanosis are among the later symptoms. Symptoms of circulatory obstruction are also common. Many tumors of the thymus are very malignant and prove fatal rapidly. Death most commonly occurs from asphyxia. In five cases reported by Ambrosini,[9] death occurred in less than ten months from the onset of symptoms. However, some cases progress relatively slowly, and the tumor is an accidental finding at necropsy. (Rubaschow, and Mandlebaum and Celler.[10]

Janeway [11] reports nine cases of mediastinal tumor treated by radium and roentgen rays. In only four of the cases was tissue available for microscopic examination, but Janeway considers that all of the tumors resemble thymic neoplasms clinically. His treatment in some of the cases seemed to have modified the course of the disease considerably.

Ewing [12] classifies malignant thymic tumors in three groups: (1) lymphosarcoma or thymoma; (2) carcinoma, and (3) spindle-cell sarcoma or myxosarcoma. Tumors belonging to the last group are said to be very rare. In the first group, Ewing includes two types of tumors. The first type resembles an infectious granuloma of the structure seen in Hodgkin's disease. Lymphocytes, plasma cells and irregularly dis-

7. Rubaschow: Virchows Arch. f. path. Anat. **206**:141, 1911.
8. Symmers, Douglas, and Vance, B. M.: Epitheliomas of Thymic Origin, Arch. Int. Med. **28**:239 (Sept.) 1921.
9. Ambrosini: Thèse de Paris, 1894.
10. Mandlebaum and Celler: J. Exper. Med. **10**:308, 1908.
11. Janeway, H. H.: Ann. Surg. **71**:460 (April) 1920.
12. Ewing, James: Surg., Gynec. & Obst. **22**:461 (April) 1916.

tributed larger polyhedral cells compose these tumors. The presence of the large polyhedral or giant cells has been much stressed by the investigators describing this type of tumor, and when these cells were very numerous the tumors have been described as carcinomas. The second type of tumor of the first group is composed almost entirely of small round cells, and has not been distinguished from other lymphosarcomas.

Ewing describes carcinomas of thymic origin as tumors composed of coherent sheets, cords and columns of large flat or polyhedral cells lying in dense connective tissue. Cornification is absent, but concentric layers of flat cells may form structures resembling Hassell's corpuscles In other cases, the pavement appearance is less evident; the cells are chiefly cuboidal and form alveoli.

Malignant tumors of the thymus do not give rise to extensive metastases. The kidney seems to be the chief point of predilection for metastases from any form of thymic tumor. The epithelioma described by Symmers and Vance gave rise to metastatic nodules in the lungs, in the lamina of the third dorsal vertebrae and in the dura of the dorsal cord. Zniniewicz [13] records metastases in the spleen, liver, suprarenals, pancreas and kidneys and in the bone marrow of the humerus. Direct extension into the mediastinal and surrounding structures is more common than the formation of metastases. Strauss [14] reports a case in which the tumor had invaded the musculature of the auricles and completely obliterated the lumen of the vena cava by pressure. A number of cases have been reported in which the tumor caused perforation of the chest wall (Ewing, Janeway, Zniniewicz).

A few cases of thymic neoplasms have been associated with myasthenia gravis. Mandlebaum and Celler, and Jones [15] have reported such cases. Sweany [16] has reported a case of thymoma complicated by pulmonary tuberculosis.

COMMENT

Malignant thymic tumors usually prove fatal rapidly. In my second case, death ensued five weeks after the appearance of the first symptoms. In both cases, death was due to asphyxia. In the first case, there occurred also circulatory obstruction. Enlargement of the neck accompanied by dyspnea and dysphagia was the chief complaint in both cases. Both patients were under 26 years of age. It is at about this age that thymic sarcomas are most likely to occur, according to the statistics of Rubaschow.

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13. Zniniewicz: Inaug. Diss., Greifswald, 1911.
14. Strauss, S. G.: New York M. J. **110**:646 (Oct. 18) 1919.
15. Jones, W. A.: Myasthenia Gravis, J. A. M. A. **67**:1354 (Nov. 4) 1916.
16. Sweany, H. C.: Primary Tumor of Thymus Associated with Tuberculosis, J. A. M. A. **80**:754 (March 17) 1923.

It is well known that in a large number of cases of exophthalmic goiter, there is a concurrent hyperplasia of the thymus. It is of interest to note that in my first case of thymic sarcoma a simple colloid goiter was present.

The first tumor described above should probably be classed as a lymphosarcoma of the thymus. It is of the type resembling an infectious granuloma, according to the description by Ewing. The growth was composed of small round cells, larger polyhedral cells and giant cells. The larger cells were predominant. Plasma cells and eosinophilic granulocytes were numerous. The stroma was for the most part hyalinized.

The second tumor also belongs to the class of lymphosarcoma, but in this case the small round cell was predominant as in lymphosarcomas in other organs. Polyhedral and giant cells were scarce.

The neoplasms in the first case showed greater power of invasion and metastasis. The pleura, pericardium and posterior mediastinum were invaded, and metastases occurred also in the heart and kidneys. Though metastasis to the kidneys occurred in the second case, the tumor was nevertheless well encapsulated and gave no indications of tendencies in invasion. Whether the difference in structure of the two tumors is related to the difference in their manifested malignancy can only be conjectured.

SUMMARY

1. Malignant tumors of the thymus usually prove fatal rapidly. The symptoms are those of respiratory and cricultatory obstruction. Death is due to asphyxia in most cases.

2. Hyperplasia of the thymus often accompanies hyperplasia of the thyroid, particularly in exophthalmic goiter. In one of the cases of thymic tumor here described, a colloid goiter was present.

3. The two cases of thymic tumor come under the head of lymphosarcomas, according to the classification of Ewing. The first tumor resembled somewhat an infectious granuloma; while, in the second tumor, the small round cell predominated as in lymphosarcomas in other organs.

HEMOLYTIC STREPTOCOCCUS GANGRENE *

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PEKING, CHINA

Much has been written in the medical literature of all countries engaged in the World War bearing on various phases of acute bacterial gangrene produced by anaerobic organisms. But almost no attention has been given to another group of cases characterized by a rapidly developing gangrenous process from which only the hemolytic streptococcus can be recovered with regularity. These two groups differ from one another quite widely in several important respects, both clinically and pathologically. The latter is a clear cut clinical entity which can readily be recognized and whose clinical course and bacteriologic findings can be fairly well predicted.

On questioning other medical men in China, I have learned that the disease is fairly common and has a rather wide distribution in that part of the Orient; but little has been written on the subject. A review of the general medical literature indicates that the condition is relatively rare in other countries, except for one small subgroup, namely, gangrene of the scrotum and penis, individual cases of which have been reported by Seemann,[1] Hawkins[2] and Stirling;[3] while Campbell[4] has given an excellent description of five cases. Now it appears that this same condition may occur on any part of the body surface. Seemann recognized this when he compared his case of gangrene of the scrotum and penis with the cases of gangrene of the extremities reported the year before by Pfanner.[5] In five of these cases, a streptococcus was found, and it is possible that Pfanner was dealing with the condition that I am about to describe. However, some of his observations, as I shall point out later, were quite different from mine. It is quite probable that at least two of the cases of acute gangrene reported by Fedden[6] were of this type and also other cases in the older literature which were only reported clinically. There can be no doubt that the disease has been observed

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1. Seemann, D.: Gangrun von Scrotum und Penishaut nach Erysipel und plastische Versorgung der Genitalien, Deutsche Ztschr. f. Chir. **150**:145, 1919.

2. Hawkins, J. A.: Spontaneous Gangrene of the Scrotum, Mil. Surgeon **50**:419 (April) 1922.

3. Stirling, W. C., Jr.: Gangrene of Scrotum and Penis, J. A. M. A. **80**: 622 (March 3) 1923.

4. Campbell, M. F.: Streptococcus Scrotal and Penile Gangrene, Surg., Gynec. & Obst. **34**:780 (June) 1922.

5. Pfanner, W.: Zur Kenntnis und Behandlung des nekrotisierenden Erysipels, Deutsche Ztschr. f. Chir. **144**:108, 1918.

6. Fedden, W. F.: Six Cases of Acute Infective Gangrene of the Extremities, Proc. Roy. Soc. Med. **2**:213, Pt. 1, 1909.

from time to time. During the past two years I have had the privilege of studying and treating seventeen such cases, and from our records I have collected three more.

Although this series is not large, I believe that the cases will illustrate fairly clearly the clinical manifestations of the disease and will point the way to many important laboratory studies on this most important surgical organism. Some of these I will attempt to outline at the end of this paper.

AGE AND SEX INCIDENCE, LOCATION AND PREDISPOSING CAUSES

The disease occurs in the large majority of cases in males, probably because of their closer contact with dirt and their greater liability to injury. All ages are represented, from youth upward. In almost all cases, there is an initial lesion, either an injury, a hypodermic injection, a boil, a frost bite, or a scratch, but in a few cases the patient has no recollection of injury. Cases of this group subsequently progress just like the others. There is probably some minute portal of entry which has escaped the notice of the patient.

The extremities are chiefly affected, but other parts of the body may be involved. In this series, the disease developed in six instances in the foot; in three, in the leg; in one, in the thigh; in four, in the forearm; in three, in the arm; in one, in the hand; in one, in the chest wall, and in one, in the penis and scrotum. In 75 per cent. of the cases, the infection spread beyond the original site of infection to a neighboring part. After the onset of the disease, several patients gave a history of the application of Chinese medicine, and it was thought that this might be the cause of the death of the skin, but in the majority of the cases there was no such history, and a closer study of the cases has quite clearly shown that the gangrene of the skin is secondary to the necrosis of the subcutaneous tissues.

CLINICAL COURSE

The disease is characterized by its alarmingly rapid development. Usually, within twenty-four hours after the appearance of the original lesion, the affected member becomes greatly swollen, hot, red and tender, with symptoms and signs of acute inflammation spreading rapidly both proximally and distally from the original focus. The patient has a rapidly developing fever which may be preceded by a chill and is almost always followed by profound prostation. As the part swells, the stiffness, pain and increased weight render it quite useless. In some cases, the pain of onset is replaced by a numbness, which later develops into a complete anesthesia for the affected portion. The early swelling makes the skin tense, smooth and shiny. The redness is usually diffuse, and gradually fades off into normal color at the margins. In some cases, the redness appears in irregular patches with flat, indistinct outlines. In

a day or two, certain areas gradually turn darker, changing from red to purple and then to blue. About this time, blisters and bullae begin to form, in which clear yellow fluid collects. A little later, this fluid becomes dark, and if the blisters are broken, a shiny, moist dusky surface is seen beneath them. This is well illustrated by Figure 16, above. In some cases, at this stage, the member looks as if it had been extensively burned. This was true in Case 2. When this patient came to the hospital, I could hardly believe that the arm had not been burned, but repeated questioning made it evident that there had been no contact with heat, chemicals or medicines. Figures 12, above; 21, below and 24 illustrate this point very well. Usually, on the fourth or fifth day, the purple areas of skin become frankly gangrenous. They first become black, as illustrated by Figure 25, and then a greenish yellow, particularly at the margins. This condition is shown in Figure 18, above. The whole process was considerably slower in this case. From the seventh to the tenth day, the line of demarcation becomes sharply defined and the dead skin begins to separate at the margins or break in the center, discharging pus and revealing an extensive necrosis of the subcutaneous tissue. This stage is seen in Figures 19 and 21, above. Sometimes, the area of skin necrosis is very small, while the subcutaneous gangrene is very extensive. This fact may occasionally be recognized on admission, as in Case 14, illustrated in Figure 18, below. In other cases, the extent of the subcutaneous necrosis is not recognized until an incision is made. Then it is found that the whole length of the part has to be opened, as shown in Figures 5, above; 6; 12, below; 14; 16; 17; and 23 below, or that a large part of the whole circumference of the member is undermined, as illustrated by Figure 20. Up to the time the dead skin separates, fever continues, the prostration increases from day to day, and the patient becomes weaker and more and more emaciated.

In a certain number of untreated cases, as illustrated by Figures 8, above, and 11, left, the process at this time comes to a standstill of itself and the dead skin falls off, leaving a large ulcer with undermined edges and granulating base. The slough rather quickly liquefies and drains off from beneath the undermined skin, which then heals to the granulating surface. After that the whole wound granulates, contracting as it does so, and later may become entirely epithelialized. Occasionally, lateral pockets of pus form as the slough liquefies. The pus may then discharge from beneath the edge of the ulcer for several weeks, or may be released by a subsequent sloughing of the overlying skin, or by incision.

In more severe cases, the process continues to advance rapidly until several large areas of skin have become gangrenous, and the intoxication renders the patient dull, unresponsive, mentally cloudy or even delirious. About this time, pulmonary symptoms and signs denoting bronchopneumonia or lung abscess may develop. Metastatic abscesses may

appear in any part of the body, but chiefly in the subcutaneous tissues. The organisms seem to find a more favorable environment for growth in the subcutaneous layer than in other tissues of the body. These metastatic abscesses almost always develop without local reaction. There is no redness, and only moderate swelling and tenderness are present. Sometimes, a putty-like edema appears in the skin overlying such a collection of pus, but at other times it requires careful search to locate the focus. The patient does not complain of pain, and after one or two abscesses have been opened, he actually tries to conceal the presence of new ones, preferring to suffer the slight discomfort of the abscess rather than the discomfort of operation and subsequent dressings. The presence of such abscesses is almost always made evident by a rise in tem-

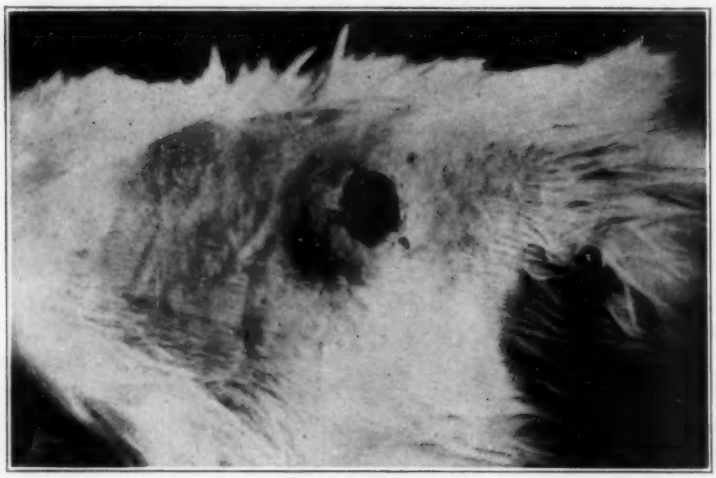

Fig. 1.—Lesion obtained in rabbit with hemolytic streptococcus recovered from Case 11. The area of necrosis and the more extensive subcutaneous involvement are shown.

perature of a degree or two, so that the surgeon is warned. Case 11 had fourteen such abscesses. In all of these abscesses, the hemolytic streptococcus has been found; but in Case 12, the secondary abscess of the elbow also contained hemolytic and nonhemolytic *Staphylococcus aureus,* the same organisms that were found in the leg, with the exception of *B. welchii.* As emaciation proceeds, bed sores may develop, particularly in those cases in which there is a positive blood culture. It is probable that pressure also favors the localization of the organism in the subcutaneous tissues.

It is obvious that these complications are minimized by the wide exposure of the originally infected tissues and the consequent outpouring of the organisms and their toxins. Therefore, even in severe cases, if

proper treatment is instituted early, the process usually comes to a standstill; separation of the dead tissue and resolution take place, and metastatic abscesses do not develop. If, before treatment is instituted, some unapproachable focus develops, as for instance in the lungs, that focus in turn may send out metastases. This was probably true in Case 15, in which metastatic abscesses appeared long after the slough had entirely separated from the arm.

Lymphangitis is very rare in this condition and in only a few cases is there any enlargement of the regional lymph glands. Occasionally, there is a phlebitis of the neighboring veins. In view of the nature of the gangrene, it is surprising that this is not more often seen. In a few cases, erysipelas is present. This was true in Case 15 of this series, in which the patient came in on the seventeenth day of his illness. I was not able to determine when the erysipelas had started. A few days after admission, a second area of erysipelas developed on the face, without any subsequent necrosis there. Erysipelas may arise, however, after the gangrenous process has subsided and may spread extensively both proximally and distally. This occurred in Cases 6 and 8 of this series. In Case 6, it appeared on the eighteenth day of the disease, and in Case 8, it appeared twice during the course of treatment, once on the twentieth and once on the eighty-first day of the disease. In this respect, Seemann's case and the cases of Pfanner's series differ quite strikingly from mine. Pfanner reports that his cases all began as erysipelas and that the gangrene was secondary. He calls the disease "necrotising erysipelas." He writes: "The subcutaneous necrosis extends about a hand's breadth above the erysipelas. When early incisions were made to the limits of the subcutaneous necrosis, the erysipelas went no further and the progress of the necrosis also stopped." This was certainly not true in this series. Only one patient had erysipelas when admitted, and it developed after admission in two others. It spread quite independently of the necrosis, indeed, while the latter was clearing up. It required no special attention and behaved like ordinary erysipelas. In this series, it seems definitely to have been a secondary complication, just as it may be in any form of infection with the hemolytic streptococcus. In the past two years, the records of this hospital show erysipelas developing secondarily to hemolytic streptococcus mastoid operations in two cases, to hemolytic streptococcus abscesses in two cases, to hemolytic streptococcus postoperative wound infection in one case, to other wounds in which no previous culture had been taken in twelve cases and spontaneously in ten cases, all without gangrene.

Usually, the temperature in these cases is not very high. The great majority of patients have fever on admission, between 37.4 and 39 C. (99.3 to 102.2 F.). The prostration, however, is striking, and the puise is rapid, from 80 to 120 and in severe cases, 160. The pulse rate falls somewhat more slowly than the temperature after operation.

In about 40 per cent. of the cases, a faint trace of albumin is present in the urine on admission, but it usually very quickly disappears after operation. This transient albuminuria is probably similar to that which is found in other acute intoxications.

The white blood cell counts are of interest in this disease. Some years ago, Sondern [7] demonstrated that an estimate of the severity of any inflammatory process could be made by a careful comparison of the relation of the polymorphonuclear percentage to the total white count. After studying a large series, he concluded that "the increase in the relative number of polymorphonuclear cells is an indication of the severity of the toxic absorption, while the degree of leukocytosis is an evidence of the body resistance toward the infection." Gibson,[8] later, used a standard chart to express this idea graphically. This he found to be fairly accurate between the levels 10,000 P. 75 and 30,000 P. 95. If, on the chart, a line is drawn from the figure representing the total count to a figure representing the polymorphonuclear percentage, it rises or falls according to the relative disproportion of the two counts. Both Sondern and Gibson found that, in intra-abdominal gangrenous processes, the "resistance line" usually ascends, indicating that the prognosis is bad. But later, after surgical interference, toxic absorption may be less and the body gain control. Then the line becomes level or takes a downward turn.

Taking this series as a whole, the average figures give a falling "resistance line," showing on the average a good resistance against the infection. Of the individual cases, nine of seventeen so counted had a rising line, showing that the battle was going against the patients when they came into the hospital. All of the four fatal cases were among this number, three others were in old men who recovered, one other was in a man of 44 and the other in a boy. In those who recovered, subsequent counts, when taken, showed a level or a falling line. One blood count of 76,000 is of special interest. At first, a leukemia was suspected; but there were no signs of this disease; the white cells were of normal appearance, and the count gradually fell to normal. In many of the cases, there was a progressive loss of red cells and hemoglobin during the active course of the disease, with a gradual recovery later during convalescence.

Positive blood cultures with hemolytic streptococcus were present in seven of the seventeen cases in which cultures were taken. It is quite possible that this figure would have been much higher if cultures had been taken more frequently. In three of the fatal cases, there was a positive blood culture. It is surprising that in the other there was not.

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7. Sondern, F. E.: The Present Status of Blood Examination in Surgical Diagnosis, Med. Rec. **67**:452, 1905.

8. Gibson, C. L.: The Value of the Differential Leukocyte Count in Acute Surgical Diseases, Ann. Surg. **43**:485, 1906.

It was unfortunate that another test was not made on the day of death or postmortem. It has been shown by Hopkins and Parker [9] that, when streptococci are injected intravenously into rabbits in nonlethal doses, the organisms disappear rapidly from the blood. It is quite probable that in a disease of this kind, large numbers of organisms are constantly being thrown into the venous blood stream and are destroyed either in the blood or in the tissues. In human beings they must, of course, run the gauntlet of two capillary beds before reaching the vein from which the cultures are taken. It may very well be that cultures taken from the vein coming from the part or from an artery would show a larger percentage of positive results. A positive blood culture is by no means an omen of death, as Martin [10] has recently shown, and as this series indicates. The patient in Case 1 left the hospital against advice with a positive blood culture, and efforts to follow up the subsequent course have proved vain; but in three other cases (Cases 5, 11 and 13) the patients recovered after having positive blood cultures. However, the prognosis is certainly less favorable, and the uttermost responsibility is placed on the surgeon to find and eliminate every approachable focus of the infection. Sometimes, the blood culture is negative when the patient comes in and becomes positive after operation, when tissues are cut and blood vessels are broken. This is illustrated by Cases 11 and 13. Undoubtedly, there is a shower of organisms into the blood at that time. This brings up the question as to how much or how little should be done at the time of operation. Here, the surgeon is called on to use very careful judgment. It is obvious that he must not do more harm than he does good by his incisions.

TREATMENT

Incisions should be made from the gangrenous area proximally and distally as far as the subcutaneous necrosis extends, but no farther. It is not necessary and may even do more harm than good to cut into the zone of cellulitis. The gangrenous skin should be excised as soon as the line of demarcation has developed to a point where the dead skin can be removed without causing much bleeding. Immediately after operation, if it is possible, the part should be put in a hot water soak at from 40 to 42 C. (104 to 107.6 F.). Saline or antiseptic solutions seem to have no superiority over water. The heat produces a hyperemia and the toxic substances find easy exit into the water. It is convenient to soak two hours out of three in the day time and one hour out of three

9. Hopkins, J. G., and Parker, J. T.: The Effect of Injections of Hemolytic Streptococci on Susceptible and Insusceptible Animals, J. Exper. Med. **27**:1 (Jan.) 1918.

10. Martin, Walton: The Significance of Bacteria in the Blood Stream from a Surgical Standpoint, Ann. Surg. **76**:421 (Oct.) 1922.

at night. The rest is good for the patient and keeps the part from becoming macerated. The wet bandages are not removed between the soaking periods. Parts which cannot be soaked should be covered with hot poultices, changed every hour or two. At the end of twenty-four hours, the cellulitis is usually greatly diminished, and in forty-eight hours, it may be all gone. Then surgical solution of chlorinated soda (Dakin's solution) should be applied, either in the usual way by Carrel tubes or by compresses soaked in the solution and changed every two hours. The latter method carries away more of the exudate and slough, but in the early stages the tube instillation seems to give better antiseptic contact. The chief action of the surgical solution of chlorinated soda at this stage is to hasten the separation of the slough. Each day as much slough as possible should be carefully removed from the undermined normal skin, so as to avoid the breaking of the blood vessels passing through the slough. Sometimes, extensive undermining pockets receive better drainage by counter incisions (as was found in Cases 5, 8 and 11). When the slough has entirely separated and the organisms are largely killed or mechanically removed, the undermined skin becomes adherent by the healing of the opposing granulating surfaces. While this healing is going on, the whole wound contracts and the new epithelium begins to grow in from the adherent edges. Small ulcers may be completely epithelialized without skin grafting; but in most cases, the ulcer is so large that it is advisable to graft. The time when this may be done varies considerably. In this series, the average time was about the fiftieth day of the disease, but occasionally it may be much earlier. The technic in most of the cases in this series has consisted in the employment of Reverdin's method of transplanting small islands from 5 to 10 mm. in diameter on the clean granulating surface, in a manner very similar to that which has recently been so well described by Schlaepfer.[11] Afterward, the grafted area is left exposed to the air for from six to eight hours. Then zinc oxid ointment is placed on the skin margins, and a single layer of coarse meshed gauze is placed on the surface. This is held in place by the ointment at the margin, and while it holds the grafts in place, it allows the free discharge of exudate. Surgical solution of chlorinated soda is then applied every two hours by means of compresses. On the third or fourth day, the grafts, if they live, have become firmly attached, and the layer of gauze may be removed. The condition of the grafts in this stage is shown in Figures 2, below; 4, above and 22, below. Complete epithelialization occurs in from two to four weeks. Figures 4, below; 7, below; 10; 11, right; and 13, right show various stages of this process.

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11. Schlaepfer, K.: Closure of Granulating Wounds with Reverdin-Halsted Grafts, Bull. Johns Hopkins Hosp. **34**:114 (April) 1923.

When the foregoing technic is carefully followed, the success of the skin graft has seemed to depend chiefly on the amount and character of the exudate present. The streptococcus is so resistant in the wounds that we have not waited until they were sterile before skin grafting, but have judged the time for grafting by the clinical appearance of the wound. The surest clinical indication that grafts will survive seems to be the new growth of epithelium from the ulcer margin. As long as the edges are undermined, pus continues to pour forth, and if grafts are planted on the neighboring granulating surface, they will be washed off or digested by the exudate. This is well shown in Figure 22, below, in which it is seen that the grafts are living everywhere except where the margin is slightly undermined. Or, if pus is discharging profusely from the granulating surface, the grafts will be lifted up by the exudate and lose their nutrition. Large Reverdin grafts or Thiersch grafts will not be successful unless the exudate is almost nil.

In most cases, amputation is quite unnecessary, because the infection is superficial and can be combated by superficial incisions. When there is bone involvement as a result of an initial injury, I am in favor of early amputation. I believe that in Cases 10 and 12, we made a mistake in delaying amputation; but in Case 15, amputation would have done no good and if we had Case 5 to treat again, we would not amputate.

"Antistreptococcus" serum was not used in any of the cases.

RESULTS OF TREATMENT

When the patients come in, the infection seems to be overwhelming; but some of them make surprising recoveries. This may be due to a certain racial resistance to the hemolytic streptococcus, but a more important factor, I believe, is the tendency of the disease to localize itself and for the destroyed tissue to separate and be cast off. Of this series, fifteen out of twenty recovered completely. Some of the end-results are seen in Figures 4, below; 8, below; and 10. The patient in Case 1 left the hospital in a critical condition, against advice, and we have not been able to determine his subsequent course. Four patients died. Of these, special mention should be made. In Case 10, there was a compound fracture of the radius with a resulting osteomyelitis and a burrowing along muscle planes. A metastatic lung abscess which broke into the pleural cavity was the overwhelming complication. In Case 12, there was a gas bacillus infection following the hospital operation. The organism was present in the wound, but there was no evidence of its activity until after the operation, and I am confident that it did not play a part in the original gangrenous process, although I believe that it was the principle cause of death. In Case 15, the patient was desperately ill on admission and was expected to die almost every day of his stay in the hospital. From the first, there was no effort at healing.

Erysipelas was present in two places. The blood culture was repeatedly positive, and the number of the metastatic abscesses increased until his body was overwhelmed. In Case 19, the patient was pulseless when he came in, and he was overwhelmed with the severity of the intoxication. The whole right side of the chest was involved, and the amount of poison absorbed must have been enormous.

PATHOLOGY

The infection essentially produces a gangrene of the subcutaneous tissues. Secondarily, but very rapidly, it causes death of a part of the overlying skin, apparently by cutting off its blood supply. When this dead skin separates at the margin, it may often be removed in one large plaque containing all of the tissues down to the muscles and tendons. In some of the cases, when dead skin was removed, the underlying tissues presented rough granulations with here and there shaggy fragments of slough, as in Figures 2, above; 3, and 7, above. In certain other cases, in which the healing processes were slower, the muscles and tendons stood out almost as in an anatomic dissection. This is illustrated by Figures 12, below; 14, and 20. On removal of the dead skin, there is found on all sides an undermining of the relatively normal skin due to the more extensive subcutaneous gangrene; while still farther out, there is a relatively narrow zone of cellulitis from which organisms may be cultured. Further still is a relatively wide zone of sterile edema. In this series, small exploratory incisions were made, and cultures were taken from these zones in several of the cases. The lateral undermining is clearly shown in Figures 2, above; 3; 5, above; 9; and 17, above. Passing through this slough, patent blood vessels are found. If these are cut or broken, they bleed profusely and later the corresponding skin becomes necrotic. This was well illustrated in Case 15; for, on the fourth day after operation, when several of these vessels were broken, the skin on the ulnar side of the forearm became gangrenous between the two incisions. If these blood vessels are not cut or broken, the subcutaneous slough, as it separates, may be removed from around them and the overlying skin be preserved. These vessels may be seen in Figure 12, below. In a few cases, the cutaneous nerves are seen passing through this slough. Sometimes, they are destroyed by the process, and anesthesia results. Others are exquisitely painful to touch or on the application of surgical solution of chlorinated soda, or even on exposure to the air. This pain disappears later as the nerves are destroyed or as they are covered by granulation tissue. Some of the cases also show a preservation of the long subcutaneous veins, as illustrated in Figures 5, 14 and 20, below. No opportunity was offered to determine whether or not these became thrombosed, but certainly they did not become necrotic,

and later very quickly became covered over with granulation tissue. These facts seem to demonstrate that the blood vessels are more resistant to the necrotic process than is the subcutaneous fat. Later, however, some of them, at least, are invaded by the organisms and become thrombosed, as the microscopic examination demonstrates. It seems reasonable to suppose that the gangrene of the skin is due to a thrombosis of these skin vessels, for the deep vessels are not thrombosed and the deep structures are not involved in the gangrenous process. The infection does not go into the muscles or bone unless the original injury exposes those structures. Even then, the infection does not enter the muscles, but rather separates them one from another. This occurred in two of this series, Cases 10 and 12. Later, in Case 12, the gas bacillus gained a foothold, and directly infected the muscles and turned them black; whereas, they were of normal appearance at the time of operation fourteen days after the original infection had been active.

The arm in Case 10, which was amputated on the thirteenth day of the disease, offered excellent material for microscopic study, and the pathologic findings in the skin in that case were confirmed by an examination of the skin taken from several of the other patients. Sections of the skin near the areas of gangrene showed a very acute inflammatory process. The whole tissue was edematous, particularly the subepithelial tissues. There was a very active fibroblast proliferation, evidently a reparative process. The blood vessels were greatly dilated and some of them were filled with broken down pus cells and red cells. Others showed a partial occlusion by new connective tissue growing from the intima and by plugs of pus cells, while others were completely thrombosed (Fig. 26). Both venules and arterioles were involved in this process. At the margin of the gangrene, the epithelium had been destroyed and the surface was covered with a fibrinous exudate filled with polymorphonuclears. On the deep surface of the undermined skin, near but not in the gangrenous area, there was very active granulation tissue formation, with many new-formed blood vessels. Sections taken from the undermined skin at some distance from the gangrenous area also showed marked edema and a dense infiltration of all the tissue with all types of wandering cells, large mononuclears and polymorphonuclears predominating. There was very active and very vascular formation of granulation tissue on the deep surface. A few of the deeper vessels in the subcutaneous fat were partially occluded and the lumina filled with pus cells. Sections prepared with Macallum's stain for demonstrating bacteria in tissues showed streptococci in great numbers in the granulation tissue and invading it toward the skin surface for a short distance. In the gangrenous tissue, they were present all through the skin. In the blood vessels that contained pus cells, there were countless organisms,

usually in the diplo form, but there were numerous chains of four or six organisms (Fig. 27). A cross-section of some of the communicating vessels showed their lumina to be contracted, but patent. They were surrounded by granulation tissue in which there was very active formation of new blood vessels, probably a compensating mechanism. Streptococci were found in the more superficial layers of the granulation tissue. Sections of the surface of the muscles showed very vascular granulation tissue covered by a fibrinous exudate, but there was no thrombosis. The section from the brachial vessels showed no thrombosis. The vessels were filled with blood in which there was a large proportion of polymorphonuclears.

BACTERIAL STUDIES

In the first eight cases, cultures of the pus were sent to the clinical laboratory for routine examination. In such examinations, usually only the predominating organism is reported. In these cases, with one exception, the only organism reported was the hemolytic streptococcus. In Case 1, a staphylococcus and a gram-positive bacillus were also found, but were not further classified. When the disease came to be recognized as a clinical entity, it was thought advisable to determine, if possible, whether the hemolytic streptococcus was the primary factor or merely a secondary invader. Dr. Ten Broeck of the department of bacteriology consented to make a study of any other organisms which might be present. The nature of the infection made us suspect that there might be some of the anaerobic groups, and careful efforts were made to determine their presence. At operation, cultures were made from the limits of infection, as well as from the open wounds. It was found, however, in the last twelve cases so studied, that the hemolytic streptococcus was the only organism invariably present. In four cases, it was found in pure culture; in four other cases, at least one of the incisions showed a pure culture. The other organisms which were found were always fewer in number than the streptococci and none of them appeared regularly enough to consider it in any case as the causative organism. *Staphylococcus aureus* appeared five times, in two of which the hemolytic type was present. *B. pyocyaneus* was present twice; *Staphylococcus albus,* three different gram-positive bacilli and one gram-negative bacillus appeared once. In only one wound was an anaerobic organism found. This was in Case 12 in which an organism of the *B. welchii* group appeared in the pus taken at the time of operation, although there was no evidence of its activity in the original infection. Dr. Ten Broeck has said, as a result of his study, that he has "no evidence that there is any organism constantly present other than the hemolytic streptococcus which can be obtained by the ordinary anaerobic or aerobic methods of culture." The question of a filterable virus has not been pursued.

ANIMAL INOCULATION

In order to add confirmatory evidence, if possible, to the result of the bacterial study which demonstrated the constant association of the hemolytic streptococcus and no other organism with the disease, an attempt was made to obtain typical necrotizing lesions in white rabbits by the injection of these organisms. A single colony recovered from an innoculated 10 per cent. horse blood-agar plate was planted in plain broth, and after eighteen hours incubation, from 0.25 to 0.50 c.c. was injected into or immediately under the skin in the center of a shaved area on the rabbit's side. Six of the thirteen strains (VIII, X, XI, XV, XIII and XX) produced a lesion similar in many respects to the clinical lesions. In the first twenty-four hours, an irregular area of redness and edema appeared from 1.5 to 2 cm. in diameter. During the next day, it spread a little and the edges became a little more sharply defined, while in the center an irregular patch of discoloration appeared. By the third or fourth day, the center was frankly necrotic, and the whole lesion, now from 2 to 3 cm. in diameter, stood up like a button from the surface, with dilated blood vessels coursing beneath it (Fig. 1). In no case did the lesion spread extensively, but usually came to a standstill on the fourth or fifth day. By that time, the line of demarcation had become sharp, and a few days later the necrotic skin began to separate at the margin, revealing a subcutaneous necrosis with the formation of pus and slough and an undermining of the skin on all sides.

With Strain X, in which separation of the necrotic skin took place on the eighth day, a culture was made of the pus, and it was found to be sterile, although a smear showed large numbers of streptococci. With Strain VIII, the rabbit died on the fifth day and hemolytic streptococcus was recovered from the heart's blood and from the pus in the local lesion. With Strain XV, the animal died on the seventh day, and a positive culture of hemolytic streptococcus was obtained from the local lesion, while the heart's blood showed both hemolytic streptococcus and the bacillus of rabbit septicemia. The other three animals survived, and the lesions healed very slowly. With one of the other strains, XIII, a necrosis began to appear on the third day and spread on the fourth, but the rabbit died on the evening of the fourth day, with hemolytic streptococcus in its blood, without the development of a typical lesion. With two strains, XVII and XIX, death occurred promptly within forty-eight hours, with hemolytic streptococcus in the blood and without any local lesion. With two strains, VII and XII, swollen areas were produced with only a small spot of central necrosis, from 2 to 3 mm. in diameter. These persisted for a long time, and the necrotic points formed very adherent scabs. With the other two strains, IX and XVI, no lesion of any kind was obtained. The earlier experiments were all controlled with

the same quantity of sterile broth. This was in every case quickly absorbed, leaving no trace. Control rabbits with two heterologous strains were also negative. At the time Strain X was being tested, two control rabbits were injected, one with the gram-positive bacillus obtained from the same case and the other with a mixture of equal parts of the streptococcus and bacillus. The result was negative in the first; while, in the second, a swelling was produced with a small pinpoint of central necrosis. This remained as a small nodule, which became firmer with age. After three months, it resembled a fibrous tumor, but on its removal it was found to be cheesy, sterile pus. No organisms were found in a smear. It was interesting to note that, with all of the animals injected which survived, as well as in one with a burned area and another with a frozen area on its side, hair grew out very much more rapidly from the affected area than from the neighboring skin, owing apparently either to the stimulus of the injured tissue or to the reaction of the body to the injury.

LABORATORY PROBLEMS INVOLVED

The cases presented in this paper illustrate a peculiar type of infection in which the hemolytic streptococcus appears to be the active causative agent. The clinical entity is so clear cut that it is reasonable to suppose either that the organisms causing it have some essential common characteristic in which they differ from other strains of streptococci, or that some physical accident of introduction causes them to multiply in the particular body plane in which they are found. The latter hypothesis would hardly account for the fact that the metastases also tend to occur in the subcutaneous tissues. Also, the varieties of the initial lesion point to a varied depth of entrance of the organism. It seems more logical to look for some characteristic of growth that may permit the organism to attack the body in the manner it does. The peculiar characteristics of the action of the organism are these: It causes an extensive necrosis or sloughing of the subcutaneous fat, which tends to be a self-limiting process. It invades the blood vessels of the skin and causes a thrombosis, with subsequent death of the skin. It gets into the blood stream and forms metastatic lesions in the subcutaneous tissues elsewhere with little or no reaction and no gangrene unless there is pressure there, as in bed sores.

What characteristics of growth could be responsible for these actions? Can any laboratory tests determine these characteristics? One thinks first of all of the relatively easy and classic methods of classifying streptococci according to their morphology, or their action on blood agar, in blood cell suspensions and on the various sugar mediums. These tests were made with the organisms of this series, but without finding a common characteristic in which they differed from control streptococci

obtained from other sources. These strains were alike in falling into the Beta group of Brown [12] by their manner of growth on blood-agar plates. All formed small, slightly irregular, grayish white colonies, but they varied considerably in the size and clarity of the hemolytic zone, and when films were made from the plates, the strains were found to vary considerably in size from one another. When grown on plain broth, all strains but one were found to form a sediment, with a flocculent or granular precipitate, leaving a relatively clear supernatant fluid. In liver digest broth, they grew more diffusely, and the sediment was more mucoid. In 1 per cent. dextrose broth, they all formed a sediment in heavy flakes. In plain broth, they varied somewhat in the length of the chains and in certain of them coccoid forms were numerous. In digest broth and dextrose broth, these "involution" forms were present in all of the strains. In the sugar mediums, all were found to ferment salicin and saccharose; while none of them fermented inulin and raffinose. They varied in their action on mannite and lactose. Nine fermented lactose but not mannite. Three fermented mannite but not lactose. One fermented neither. They all hemolysed both sheep cells and human cells in 5 per cent saline suspension, though not all to the same degree. Five control strains of hemolytic streptococci behaved much in the same way.

Agglutination tests have been used by many investigators in an endeavor to group streptococci in the same way in which the pneumococci are grouped, but without the same success. Streptococcus immune serum is difficult to obtain, and the streptococcus has a bad habit of auto-agglutinating. A number of workers have devised ways of avoiding this phenomenon in most cases, notably Havens,[13] who uses the upper layers of a blood broth culture for his bacterial suspension. In this laboratory, we have not been able to produce any agglutinating serum for these organisms in cats or rabbits, although we have used a number of the approved methods. Efforts are being continued along this line. One would expect that the patients surviving this infection, having had a constant vaccination from the lesions for weeks or months, would develop some immune bodies in their serum, or at least some agglutinating antibodies. I have found that such is not the case in seven of these patients, tested at various lengths of time in the course of the disease. In Case 10, a test was made on the eighteenth day of the disease; in Case 20, on the twenty-fourth day; in Case 11, on the twenty-fourth, eighty-seventh and one hundred sixtieth days; in Case 13, on the thirty-

12. Brown, J. H.: The Use of Blood Agar for the Study of Streptococci, Rockefeller Institute for Medical Research, Monograph 9, 1919.

13. Havens, L. C.: A Biologic Classification of Hemolytic Streptococci, J. Infect. Dis. **25**:315 (Oct.) 1919.

seventh day; in Case 14, on the forty-first and the one hundred fourteenth days, and in Case 18 on the fifty-first day. In all of the cases, there were no agglutinins in the serum either for the patient's own strain, for other strains of the series or for heterologous strains. Strain XIV auto-agglutinated consistently in all of the tests, including the controls, although with Havens' method the others all remained suspended.

Two of the commercial, European "antistreptococcus immune" serums were tested, but neither was found to contain any agglutinating antibodies for the organisms of this series. In the absence of agglutinating antibodies, one would not expect any real protective immune property in the serum. Why is it so difficult for the body to produce antibodies to the streptococcus? Douglas and Fleming,[14] on the theory that the immune bodies are produced during the course of the splitting up or "digestion" of the organisms within the animal body, digested typhoid and dysentery organisms outside of the body with trypsin and produced antibodies by injecting the organisms in various stages of digestion. They found that the organisms were more readily digested by trypsin if some of the nonprotein products were first extracted with acetone. It has been shown that gram-positive cocci resist trypsin and pepsin digestion. In this laboratory, following the lead of Douglas and Fleming, we have extracted streptococci with acetone, but found them still resistant to proteolytic enzymes. It may be that the animal body is also unable to digest the streptococcus protein. The production of a really immune antistreptococcus serum may follow the devising of some method of digesting the streptococcus protein outside of the animal body.

But cultural tests and even agglutination tests are quite artificial. Even if the strains were all alike in any of these respects, that fact would not explain their action within the body tissues. It is obvious that we must look for some more fundamental, biologic characteristic. The organisms of this series probably select the subcutaneous tissue and the superficial blood vessels in which to grow and multiply, because they find in those tissues a more favorable environment than elsewhere in the body. Pathogenic bacteria probably live at the expense of their host and utilize the body tissues and fluids for food by the action of enzymes. Stevens and West[15] have recently shown that dead streptococci have such enzymes. More important and more accurate for any quantitative determinations would be the demonstration of such enzymes in the living organism. If this were possible, what might be expected of the organ-

14. Douglas, S. R., and Fleming, A.: On the Antigenic Properties of Acetone Extracted Bacteria, Brit. J. Exper. Path. **2**:131 (June) 1921.

15. Stevens, F. A., and West, R.: Peptase, Lipase and Invertase of Hemolytic Streptococcus, J. Exper. Med. **35**:823 (June) 1922.

isms of this series? One would certainly expect either a more active lipolytic or a more active proteolytic ferment than is found in other strains of streptococci. Experiments along these lines are being pursued in this laboratory and the results will be reported in other papers. Preliminary experiments carried on with the assistance of Mr. W. P. Thompson of the fourth year class of the College of Physicians and Surgeons of Columbia University, working for several months in this laboratory, seem to show that the answer to the problem may be found in the demonstration of a more active lipolytic ferment than is found in other strains of hemolytic streptococci.[16]

The first five cases were observed during a transition period at the end of the service in the old hospital and the opening of the new hospital. Unfortunately, the records are therefore not as complete as they should be. Some of them were lost in the transfer, but the data and photographs unmistakably group them with the condition described. Two of them, Cases 2 and 3, were personally cared for by me.

REPORT OF CASES

CASE 1.—*History.*—*S. K. L.*, a soldier, aged 30, admitted, Feb. 20, 1921, four days before admission, developed a small boil on the dorsum of the foot between the first and second toes. It ruptured on the second day, and the whole foot and leg very rapidly became swollen up to the knee. The patient was unable to walk, and marked fever and prostration were present.

Physical Examination.—The patient looked sick. The tongue was coated. The temperature was 38.2 C (100.7 F.); pulse, 112; respiration, 22. There were marked redness, swelling and tenderness all over the right foot and leg. An area of superficial gangrene of the skin was present, all over the dorsum of the foot and two areas of elevation of the skin on the anterior surface of the leg. The white blood count was 6,400. The urine reactions were negative. Blood culture was not taken on admission.

Treatment.—The leg was put in a continuous hot soak.

Operation.—On the fourth day, incisions were made through the gangrenous area on the dorsum of the foot and through the elevated areas on the front of the leg. The patient was greatly prostrated. A pus culture showed hemolytic streptococcus, *Staphylococcus aureus* and a small gram-positive bacillus. The soaking was continued.

Course (fifth to tenth day).—The general condition gradually grew worse, although local cellulitis diminished and the slough rapidly separated. On the tenth day, a blood culture was reported positive for hemolytic streptococcus (taken on the eighth day). Amputation was advised. On the eleventh day, the patient refused amputation, and insisted on going home (March 8), against advice.

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16. Since the completion of this paper, it has been definitely shown that the localization of the organism in the subcutaneous fat is not due to a more active lipolytic ferment. Although the lipase of these organisms as a group is slightly more active than the control strains which have been tested, the difference is not sufficiently clear cut to establish that theory. Further experiments are in progress.

CASE 2.—*History.*—T. C. S., a coolie, aged 61, admitted April 11, 1921, four days before admission was injured when a brick fell on the dorsum of the hand, producing a lacerated wound. Within twenty-four hours, the hand became swollen and red. In two days, the redness, swelling and pain had spread up the forearm to the elbow. There were fever and prostration but no chills.

Physical Examination.—The patient was greatly prostrated and in severe pain. The temperature was 36.6 C. (97.9 F.); pulse, 90; respiration, 24. The dorsum of the hand and forearm looked as if the patient had suffered a severe burn. The back of the hand, base of the fingers and a narrow strip up the center of the forearm showed gangrenous skin. Outside these areas, there were blisters and blebs, some of which had broken. Around and above the elbow, there was marked swelling and redness, and the cephalic vein stood out as a red line, tender but not thrombosed. The upper limit of redness was indistinct, fading off to normal skin. The extensor tendon and muscle action were normal. Fluid

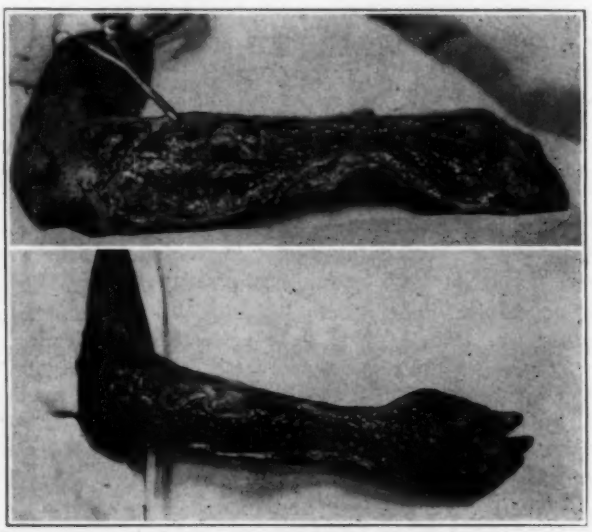

Fig. 2 (Case 2).—Above: Appearance of lesion, tenth day of disease, sixth day after admission. The dead skin has sloughed off leaving a very ragged granulating base with deeply undermined margins. A curved clamp is seen passing under a skin flap. Below: Appearance thirty-eighth day of disease, thirty-fourth day after admission, fourth day after skin graft. The grafts are all living. The margins of the wound are adherent and new epithelium is growing in.

from a blister showed diplococci, and culture showed pure culture of hemolytic streptococci. The blood count was 14,400; the polymorphonuclears numbered eighty-two. A blood culture was negative. The reactions of the urine were negative.

Treatment.—The arm was put in a hot water soak.

Course.—First day: Redness and edema spread toward the shoulder in twenty-four hours. The axillary glands were enlarged and tender. Surgical solution of chlorinated soda was applied by Carrel tubes to the necrotic skin.

Second day: There was no advance in the process. The line of demarcation was more marked, but separation was not yet possible.

Fourth day: The redness was receding on the arm. The line of demarcation on the hand and forearm was sharp.

Fifth day: Separation had begun. Pus was discharging from beneath the necrotic skin. When the dead skin was lifted up, almost all of it came off in one piece, revealing a necrosis of the subcutaneous tissues undermining the margins. Culture of pus revealed hemolytic streptococci.

Sixth day: Considerably more slough was removed from underneath the skin margins. A small area of tendon was exposed on the hand. A superficial abscess on the left heel was opened. Culture of the pus revealed hemolytic streptococcus.

Ninth day: The wound was clean, free from slough, and granulating nicely. Surgical solution of chlorinated soda was applied by compresses.

Thirtieth day: The undermining tissues were all healed. The wound surface was flat. A Reverdin skin graft was made successfully.

Fiftieth day: The area was entirely epithelialized.

May 31: The patient was discharged, well.

CASE 3.—*History.*—L. K. C., a military orderly, aged 40, admitted, April 19, 1921, was a morphin habitué. Six days before admission, the site of an injection by hypodermic needle in the forearm near the elbow quickly became red, hot and swollen, and spread rapidly downward toward the wrist. In four days, some black areas appeared on the volar surface of the forearm, which later broke at the margins and discharged pus. Fever and prostration were present from the onset.

Physical Examination.—The patient was acutely ill, and evidently in severe pain. The temperature was 37.6 C. (99.7 F.); pulse, 81; respiration, 17. There were hypodermic injection marks over the abdomen, legs and arms. The right forearm and lower third of the arm were greatly swollen, edematous and red. Several areas of frank skin gangrene were noted on the volar surface of the forearm, with other purple areas of beginning gangrene. Pus was discharging from the margins of the dead skin. The subcutaneous fat was necrotic, and the marginal healthy skin was extensively undermined. The blood count was 18,300. The polymorphonuclears numbered 72. Blood culture was not taken. A urine test revealed a trace of albumin.

Operation.—A single incision was made through all of the necrotic and necrotizing areas on the front of the forearm. Some slough was removed, and the arm was put in a hot water soak. Culture of pus yielded pure hemolytic streptococci.

Course.—First day: The swelling and redness were greatly diminished. The soaks were stopped, and surgical solution of chlorinated soda was applied with Carrel tubes.

Fifth day: The slough was separating nicely. The granulation tissue active.

Eighth day: The undermined flaps were becoming adherent.

Fifteenth day: The wound was flat. Dressings consisting of the surgical solution compresses were applied every two hours.

Twenty-fourth day: A Reverdin skin graft was made, all sections of which lived except a few at the elbow.

Fortieth day: The patient was discharged (May 27). Epithelialization was almost complete.

Fig. 3 (Case 3).—Appearance of lesion, eleventh day of disease, fifth day after operation, illustrating the ragged base after the removal of the dead skin. The curved clamp shows very well the undermining of a skin flap.

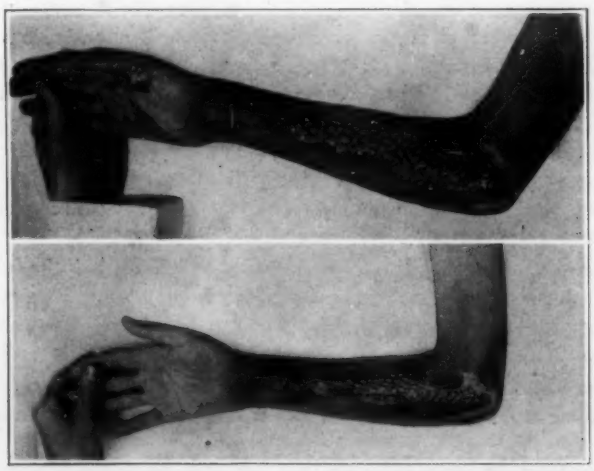

Fig. 4 (Case 3).—Above: Appearance of lesion, thirty-fourth day of disease, twenty-eighth day after operation, fourth day after skin graft. All of the grafts are living. The wound margins are all adherent and new epithelium is growing in. Below: Appearance, forty-sixth day of disease, fortieth day after operation, sixteenth day after skin graft. Epithelialization is almost complete. There is very little limitation of function.

CASE 4.—*History.*—C. C. H., a surveyor, aged 30, admitted May 13, 1921, about two weeks before admission developed several boils on the right leg. They rapidly increased in size, and within a few days redness and swelling with intense burning pain spread over the leg and up the thigh. Irregular fever was constant from the onset.

Physical Examination.—The patient was acutely ill and was prostrated. The temperature was 38 C. (100.4 F.); pulse, 102, respiration, 22. There was extensive redness and swelling of the whole right lower extremity, with an area of skin necrosis on the dorsum of the foot, inner side of the ankle and

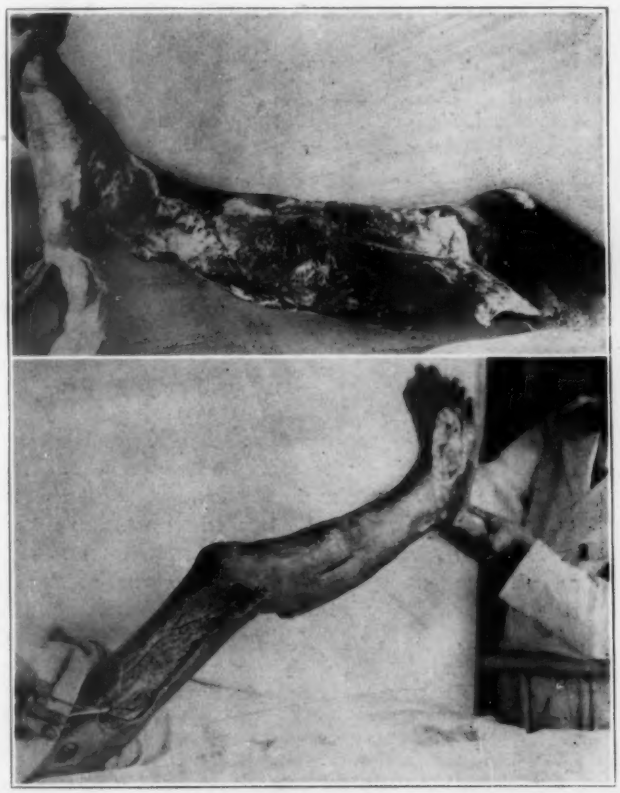

Fig. 5 (Case 4).—Appearance of lesion twenty-eighth day of disease, fourteenth day after operation. Above: The extent of the involvement of the subcutaneous tissues and the preservation of the long subcutaneous veins. Below: The marked undermining of the skin and the preservation of the long subcutaneous veins.

calf and outer surface of the thigh. The dead skin had separated in places and pus was discharging, with an undermining of the relatively normal skin on all sides. The white blood count was 16,000. Tests of the urine revealed a trace of albumin.

Operation.—Incisions were made connecting the necrotic areas on the leg and opening up the undermined areas. The leg was put in a hot water soak. A culture of pus yielded hemolytic streptococci.

Course.—First day: Soaking was continued. The slough was separating.

Second day: Further incisions were made on the leg and thigh.

Third day: The cellulitis was less. Soaking was stopped, and irrigation employing surgical solution of chlorinated soda with Carrel tubes was started.

Fourteenth day: The wounds were clean and granulating nicely.

Nineteenth day: The wounds were flat. A Reverdin skin graft of the leg was made. All of the grafts lived.

Sixty-fifth day: The thigh wound was treated by grafting. All of the grafts lived.

Seventy-fourth day: The wounds were almost completely epithelialized and the patient was discharged (July 25).

Case 5.—*History.*—C. P. Y., a merchant, aged 32, admitted May 27, 1921, five months before admission, had all of the toes of the left foot frozen. Sometime later, the dead toes were amputated. The wounds did not heal. Two

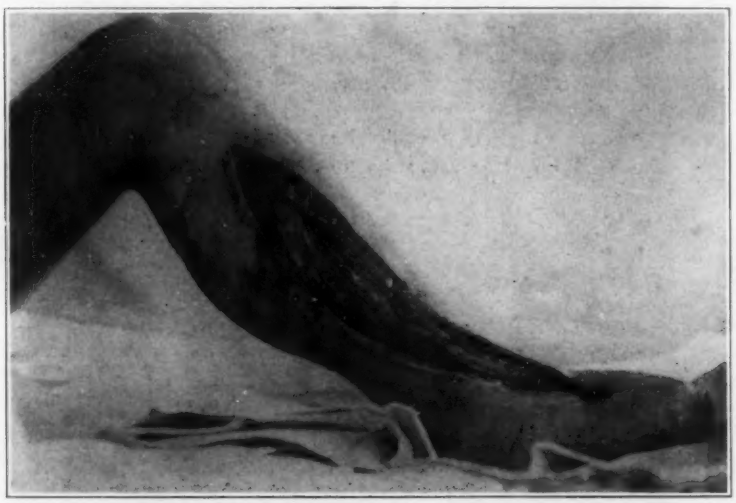

Fig. 6 (Case 5).—Appearance of lesion, eighteenth day of disease, fourth day after admission, showing the black skin which has not yet separated (separation was slower in this case than in the others); also showing the extent of the subcutaneous necrosis and the exposure of the muscles.

weeks before admission, the foot suddenly became red and swollen. The infection spread rapidly up the leg toward the knee. There were chills and fever. After several days, an area of skin on the front of the leg became discolored, and later gangrenous. The local and general process became steadily worse.

Physical Examination.—The patient looked acutely ill. The temperature was 38.2 C. (100.7 F.); pulse 94; respiration, 20. All of the toes of the left foot were missing. There was a granulating ulcer over the stump. The whole foot and leg were markedly swollen, red and tender, with a fluctuating area over the dorsum of the foot and an area of necrosis on the inner surface of the calf. The white blood count was 10,500. Blood culture revealed a hemolytic streptococcus. The urine was normal.

Operation.—A long incision on the front and inner side of the leg was made through the necrotic area down to the dorsum of the foot, revealing extensive subcutaneous necrosis. A counter incision was made posteriorly. The leg was put in a hot eusol soak. Culture of pus yielded hemolytic streptococci.

Course.—First day: The incision was extended downward to the tip of the foot. Soaking was stopped, and surgical solution of chlorinated soda was applied by Carrel tubes.

Second day: Swelling and redness were somewhat diminished.

Fourth day: There were marked liquefaction and separation of the subcutaneous slough. Fifth day: In view of the severity of the infection and the positive blood culture, it was deemed advisable to amputate at the lower third of the thigh. Thirty-third day: The wound had healed nicely and the patient was discharged, well (June 29).

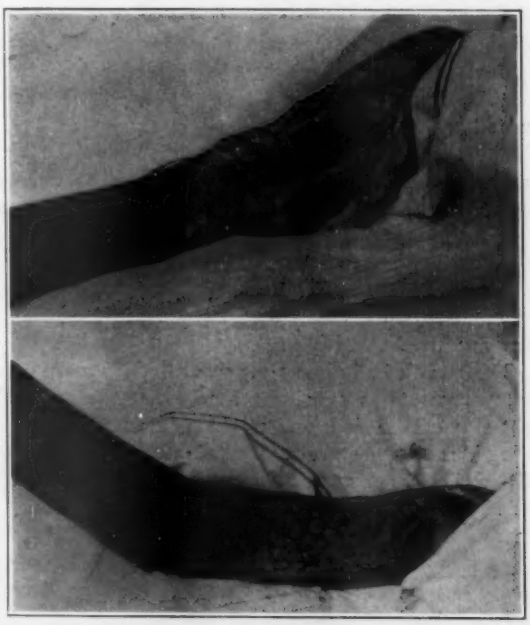

Fig 7 (Case 6).—Above: Appearance of lesion, ninth day of disease, second day after operation, showing the extent of the lateral undermining and the exposure of the muscles. Below: Appearance, forty-first day of disease, thirty-fourth day after operation, fourteenth day after skin graft, showing the new epithelium growing out from the grafts, some of which have already fused.

CASE 6.—*History.*—K. T. S., a housewife, aged 32, was admitted, July 16, 1921. Seven days before admission, without any known break in the skin, the right arm suddenly developed redness, swelling and tenderness. On the fifth day, an area on the inner surface became black, and two days later the upper portion separated, discharging pus. Fever, pain and loss of appetite had been present since the onset.

Physical Examination.—The patient was greatly prostrated and in great pain. The temperature was 39.6 C. (103.3 F.); pulse, 124; respiration, 26.

There was an ulcerated area about 5 cm. in diameter on the arm just below the axilla, covered with slough and pus. The margins were undermined from 4 to 5 cm. in all directions, with a necrosis of the subcutaneous fat. The arm below the ulcer and elbow region was swollen, red and edematous, with a purple area of skin just below the ulcer, evidently in an early stage of gangrene. The redness and swelling, unlike erysipelas, faded off gradually at the margin. The axillary nodes were palpable, but not tender. The blood count was: white cells, 14,800; polymorphonuclears, 69; red cells, 4,800,000; hemoglobin, 88. Blood culture was not taken on admission. The urine was negative. The culture of pus revealed hemolytic streptococci.

Treatment.—Surgical solution of clorinated soda was applied with Carrel tubes.

Operation (second day).—The area of necrosis below the ulcer was more marked. Incisions were made downward from the ulcer through the necrotic skin below, and the surgical solution was continued.

Course.—Third day: Large pieces of slough were cut away. The redness was subsiding above, but spreading below. A blood culture was sterile.

Fourth day: The redness was almost gone above but spreading below, and the edge was raised and sharply demarcated like erysipelas.

Fifth day: The erysipelas had spread down toward the wrist and started at the upper margin of the wound. The subcutaneous necrosis had spread slightly below, with a localization on the outer side of the olecranon. Incisions were made.

Sixth day: The slough was separating nicely. There was no advance of the erysipelas.

Eighth day: The erysipelas had died out on the forearm but had spread over the shoulder and the back.

Tenth day: The slough had almost all separated. There were active granulations. The arm process was subsiding nicely, but the erysipelas had spread all over the right side of the back and up onto the neck.

Eleventh day: The temperature was 40 C. (104 F.); the white blood cells numbered 12,400. A blood culture was negative.

Twelfth day: The erysipelas had spread all over the neck. There was no advance of necrosis.

Thirteenth day: The erysipelas was fading.

Fourteenth to twentieth day: There was rapid sealing down of the undermined edges.

Twentieth day: A Reverdin skin graft was made, all of which lived.

Thirty-first day: There was complete epithelialization. The patient was discharged, well (August 22).

Case 7.—*History.*—C. K. F., aged 80, no occupation, admitted, Oct. 31, 1921, about a month before admission had a small boil on the front of the right forearm just above the wrist. It remained insignificant for two weeks, when he cut into it. Shortly after this interference, the whole forearm on the anterior surface became red, hot, swollen and painful. Within a few days, the skin became black, and after two or three days more it began to separate. Four or five days before admission, all of the dead skin sloughed off. There were moderate fever, constant pain and sleeplessness.

Physical Examination.—The patient was in very evident pain, and was tired out. The temperature was 37.4 C. (99.3 F.); pulse, 72; respiration, 24. The ventral surface of the right forearm presented a large ulcer, 20 by 6 cm. There

were ragged undermined margins but there was a bright red, granulating base. Undermining was most marked at the upper part, where there was considerable necrosis of the subcutaneous tissue and edema of the surrounding skin. The redness faded off gradually above. The blood count was: white cells, 8,500; polymorphonuclears, 80; red cells, 4,200,000; hemoglobin, 80. A blood culture was sterile. A pus culture yielded a hemolytic streptococcus. The urine showed a faint trace of albumin. The Wassermann reaction was negative.

Treatment.—Surgical solution of chlorinated soda was applied, with Carrel tubes.

Course (November 2).—Third day: The slough was almost all gone.

Eighth day: The undermined edges had become adherent. Surgical solution of chlorinated soda was applied with compresses.

Eleventh day: A Reverdin skin graft was made. Routine postoperative treatment was not followed, and all grafts were lost.

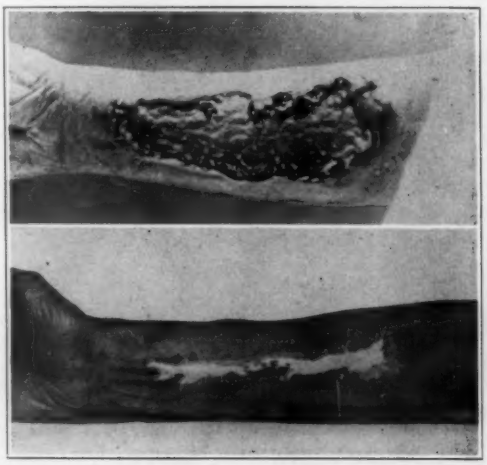

Fig. 8 (Case 7).—Above: Appearance of lesion, fifteenth day of disease and day of admission, illustrating the self-limiting process seen in a certain number of cases. The base is granulating; the margins are undermined, and there is still some slough at the upper end. Below: Appearance one and one half years after discharge, showing a small, flat, pliable scar with perfect function of the hand.

Nineteenth day: Another attempt was made at skin grafting. The technic again was not perfect, and the grafts were lost. Failure was possibly also partly due to the age of the patient and an excess of exudate.

Twenty-fifth day: The wound was contracting. The new epithelium was active.

Twenty-third day: A narrow strip of granulation tissue was not yet covered. The patient was discharged to the outpatient department for dressings.

Fiftieth day: Healing was taking place slowly.

One hundred and twelfth day: There was complete epithelialization. The patient was discharged, well (December 3).

Case 8.—*History.*—J. C. T., a merchant, aged 44, admitted, March 3, 1922, fifteen days before admission, began to have chills and fever of moderate

degree. Two days later, the upper half of the anterior surface of the right thigh became red, swollen and painful. Within forty-eight hours, the skin just below the groin became dark, and later black and necrotic. On the seventh day after the swelling began, the dead skin broke at the margins and discharged pus. Three or four days later, it completely sloughed off, leaving an ulcer. Moderate fever and severe pain had been present since the onset.

Physical Examination.—The patient looked very sick and tired. The temperature 38 C. (100.4 F.); pulse, 86; respiration, 24. The whole right thigh was greatly swollen and red from the groin to the knee. Just below the groin there was a large oval ulcer 10 by 12 cm. in diameter with ragged granulating base. Around the ulcer, the skin was inflamed and undermined, particularly on the inner side where there were two, small, perforating ulcers discharging pus and revealing a necrosis of the subcutaneous tissue. The redness and swelling faded off gradually above and below, and there was no raised margin, as in

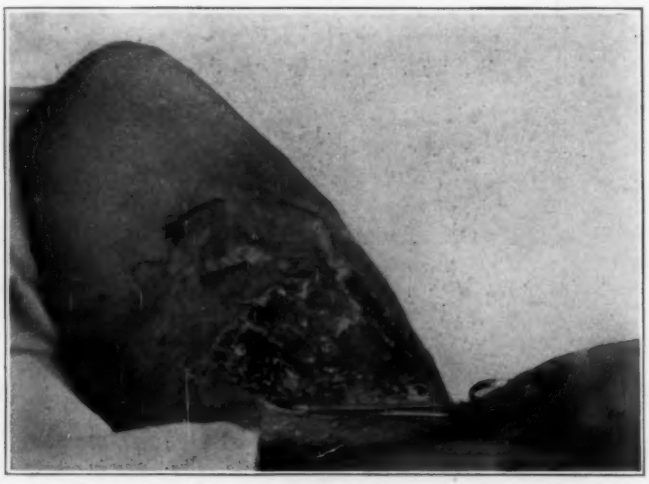

Fig. 9 (Case 8).—Appearance of lesion, fifteenth day of disease and day of admission. The dead skin has sloughed off leaving a ragged base with extensive undermining in the upper and inner quadrant.

erysipelas. The blood count was: white cells, 19,850; polymorphonuclears, 89. A blood culture was sterile. The urine reactions were negative. The Wassermann reaction was + + + +.

Operation.—Incisions were carried downward and also inward from the ulcer as far as the limits of the undermined area. A long counter incision was made on the outer surface of the thigh to drain a large lateral pocket of liquefying, subcutaneous necrotic material. A culture of pus revealed hemolytic streptococci. Surgical solution of chlorinated soda was applied with Carrel tubes.

Course.—Second day: Large pieces of subcutaneous slough were removed.

Fifth day: The wound was clearing up nicely, but the temperature was going up. At the lower end of the red area, there was now a typical, raised red margin of erysipelas. A blood culture was negative.

Sixth day: The wound was much cleaner, but the erysipelas had spread down to the middle of the leg.

Eighth day: Improvement of wound was noted, but the erysipelas had spread toward the ankle.

Tenth day: The erysipelas was fading. The temperature was down.

Fourteenth day: A blood culture was negative. The undermined skin was becoming adherent. Granulations were active. Thirty-sixth day: A Reverdin skin graft was made. A few islands were lost.

Forty-fifth day: Healing was delayed by a small, lateral pus pocket, which was opened.

Sixty-sixth day: Redness had suddenly appeared again, with an advancing red raised margin (recurrent erysipelas). The temperature was 39.4 C. (102.9 F.).

Sixty-seventh day: The high fever and spread of erysipelas continued.

Sixty-eighth day: The temperature was down and the erysipelas was fading.

Fig. 10 (Case 8).—Appearance of lesions, one year after discharge of patient. Perfect function and a pliable movable scar were the results.

Seventy-first day: The patient was discharged; all wounds were healed (June 10).

Case 9.—*History.*—T. H. H., a farmer, aged 35, admitted Nov. 6, 1922, twenty-three days before admission developed a small boil on the outer side of the right elbow. On the second day, redness and swelling spread rapidly down the forearm and up the arm. On the fourth day, the whole arm was swollen and red from the midarm down to the hand. On the fifth day, the skin began to lose its color and blisters formed. On the eighth to ninth day, the skin became black and separated from the neighboring relatively normal skin. Within three more days, the dead skin began to slough off, and the patient removed it with scissors. Fever and prostration were marked during the first ten days.

Physical Examination.—The patient did not look acutely ill. The temperature was normal; pulse, 88; respiration, 22. There was a large ulcer on the lower part of the arm extending down over the elbow on the outer side and

almost encircling the upper half of the forearm. A similar, smaller ulcer was noted on the front of forearm above the wrist. The surfaces of the ulcers were actively granulating and covered with purulent exudate. The margins were undermined in some places to a depth of from 5 to 6 cm.; with a sloughing of the subcutaneous tissues. The blood count was: white cells, 12,000; polymorphonuclears, 67; red cells, 4,100,000; hemoglobin, 90. A blood culture was not taken. The urine tests were negative. The Wassermann reaction was negative. Pus culture yielded hemolytic streptococci and a gram positive bacillus (unidentified).

Treatment.—Compresses of surgical solution of chlorinated soda were applied every two hours. The forearm was held as acutely flexed as possible.

Course.—Second day: The granulations were much cleaner. Pockets were discharging pus and slough.

Fourth day: Incisions were made, opening up all subcutaneous pockets.

Eighth day: The undermined flaps were becoming adherent. New epithelium was growing from the adherent margins.

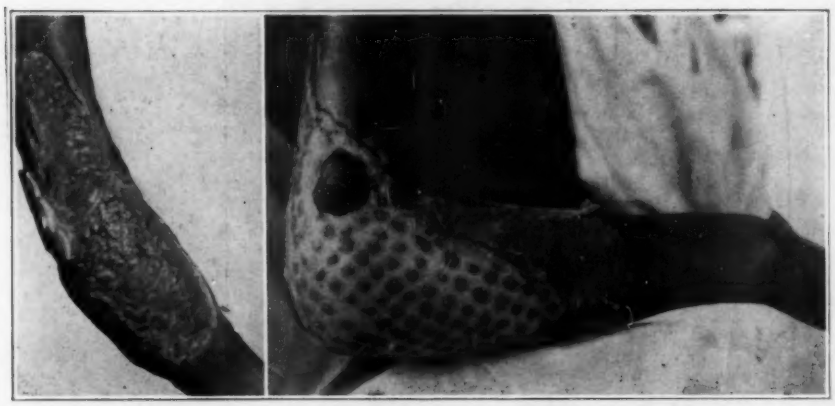

Fig. 11 (Case 9).—Left: Appearance of lesion, twenty-third day of disease and day of admission. In this case, the process was self-limiting. The base is granulating and the margins are undermined. Right: Appearance, fifty-eighth day of disease, thirty-fifth day after admission, twenty-second day after skin graft. Epithelialization is complete. The elbow joint is a little stiff but in good position for use.

Thirteenth day: The external half of the ulcerated area was grafted by the Reverdin method. All grafts were successful.

Thirty-sixth day: The internal half was grafted. Three grafts were lost.

Sixtieth day: There was complete epithelialization. The patient was discharged (January 12).

Case 10.—*History.*—C. C., a soldier, aged 54, admitted Nov. 25, 1922. Five days before admission he had a wrist crushed between two colliding sailboats. There was considerable bleeding, which was stopped by the application of some Chinese medicine. Two days later, the hand and forearm suddenly began to swell and became painful. The swelling and redness spread rapidly up the forearm, and blisters began to form. The fourth day, the skin became dusky, particularly around the wrist. The arm felt numb, but there was very little pain.

Physical Examination.—The patient looked desperately ill. The temperature was 35C. (95 F.); pulse, 120; respiration, 30. The whole right upper extremity looked as if it had been badly burned. Over the head of the ulna, there was an open wound from which pus was discharging and slough protruding. Around this wound, the skin was necrotic for a distance of from 6 to 8 cm., and was undermined for some distance up the forearm. The back of the hand and the forearm were greatly swollen, red and covered with blebs and blisters containing clear, yellow fluid. On the outer side of the olecranon, there was a fluctuating area. The redness and swelling extended up to the shoulder, gradually fading off into normal skin. There was no raised margin as in erysipelas. There was a Colles' fracture of the radius. The blood count was: white cells, 14,200; polymorphonuclears, 91; red cells, 3,600,000; hemoglobin, 100 (?). A blood culture yielded hemolytic streptococci. The urine tests were negative. The Wassermann reaction was negative.

Fig. 12 (Case 10).—Above: Appearance of lesion, sixth day of disease and morning after admission, illustrating the appearance as of an extensive burn seen in some of the cases. The opening over the head of the ulna is discharging slough and pus. It is surrounded by a grayish area of dead skin. Below: Appearance, eleventh day of the disease, fifth day after operation, illustrating the extent of the subcutaneous necrosis. Patent blood vessels are seen extending from the muscles to the skin. The slough has been removed from around them. The subcutaneous necrosis has spread at the upper end and further incision is indicated.

Operation.—An incision was first made over the fluctuating area to obtain a culture and then extended up to the limits of the subcutaneous necrosis and down to the hand. Large quantities of subcutaneous slough were removed. Three quarters of the circumference of the forearm was undermined. The wound was packed open with gauze soaked in acriflavine 1:1,000, in saline. A culture of pus yielded hemolytic streptococci, *Staphylococcus aureus* and an unidentified gram-positive bacillus (not the same type as in previous case).

Course.—First day: The pulse was rapid and weak. Edema was less There was much sloughing away of subcutaneous tissue. Surgical solution of chlorinated soda was applied with Carrel tubes.

Third day: The local condition was much improved. The pulse was 100.

Fifth day: Bronchopneumonia developed, and the patient was very toxic. The pulse was rapid and irregular. The arm was put in a hot water soak.

Seventh day: The general condition was slightly improved. A blood culture was positive.

Eighth day: The patient was considerably weaker. As there was no chance for life otherwise, amputation was made through the arm. The flaps were turned back and an acriflavine dressing was applied.

Ninth day: The patient was no worse, but the blood culture was still positive.

Sixteenth day: There was marked respiratory embarrassment. Examination of the chest revealed pyopneumothorax. Aspiration revealed thin pus, in which gram-positive and gram-negative cocci and bacilli are present, among them hemolytic streptococci. Evidently, there was an empyema resulting from rupture of lung abscess. A Kenyon closed thoracotomy was performed.

Seventeenth day: The patient failed rapidly following operation. The temperature rose to 41 C. (106 F.), and death ensued.

Case 11.—*History.*—T. E. H., a school girl, aged 17, admitted Feb. 7, 1923, fifteen days before admission suffered frost bite of the heels. The next day blisters formed. On the second day, the left foot became red, swollen and painful, with general fever and prostration. On the fourth day, the skin on the dorsum became black, while redness and swelling spread up the leg. On the seventh day, the dead skin broke at the margins and discharged pus. On the tenth day, the patient developed deafness, with moderate pain in the ears. At the same time, she became dull. For the last two days, she had been delirious at times.

Physical Examination.—The patient looked very ill. The face was dull, pallid and expressionless. The temperature was 37.3 C. (99 F.); pulse, 140; respiration, 36. On the dorsum of the left foot, there was an area of necrotic skin extending from the base of the toes up to the front of the ankle, with smaller areas of necrosis behind both malleoli. At the margin of dead skin, sloughing of the subcutaneous tissue was seen. The skin that was not necrotic was red and edematous, as was the whole leg up to the knee, where the redness and swelling gradually faded off into normal skin. Over the middle of the tibia, there was a blistering of the skin, making it look as if it had been burned. The ear drums appeared normal. The blood count was: white cells, 16,700; polymorphonuclears, 80; red cells, 3,780,000; hemoglobin, 60 per cent. A blood culture was negative. The urine showed a trace of albumin. The Wassermann reaction was negative.

Operation.—Three incisions, 10 cm. long, were made upward from the necrotic area to the apparent limits of the undermining. The necrotic skin on the dorsum and the subcutaneous tissue were removed *en masse.* A culture was taken, and one wound showed a pure hemolytic streptococcus. Others showed hemolytic streptococci, nonhemolytic *Staphylococcus aureus* and a gram-positive fusiform bacillus. The leg and foot were soaked continuously in a hot saline solution.

Course.—First day: Definite bronchopneumonia developed, with mild delirum.

Second day: There was necrosis of the skin beneath the blisters on the leg. An incision was made, revealing extensive subcutaneous necrosis.

Fig. 14 (Case 11).—Appearance of lesion, twentieth day of disease, and fifth day after operation, showing the extensive undermining of the leg. The clamp passes under a skin bridge. The tendons are bare on the foot. Laterally, some slough is still attached to the rough granulating surface. Just below knee, there is a blister, indicating beginning necrosis.

Fourth day: The cellulitis was less. Large pads of slough were removed from beneath relatively normal skin on the outer surface of the calf.

Fifth and eighth days: The right and left ears discharged pus. A culture showed hemolytic streptococci and other organisms.

Ninth day: A blood culture was positive. The granulations were active. The slough had all separated on the leg.

Eleventh day: The lungs were clearer. A collection of pus in the popliteal space was opened.

Fifteenth day: A blood culture was negative. A bed sore was developing over the sacrum.

Twenty-first to fifty-fifth day: Twelve subcutaneous abscesses developed in different places on both thighs and the leg opposite the one affected, all but

Fig. 13 (Case 11).—Left: Appearance of lesion, fifteenth day of disease and day of admission, illustrating the great swelling of the affected part. Blisters have formed on the leg in the early stage of gangrene. Right: Appearance 155th day of disease, 140th day after operation, thirty-first day after skin graft. Epithelialization is complete. There is considerable stiffness of foot and ankle joints.

one without much pain and with no local reaction. Two more negative blood cultures were obtained.

Sixty-fifth day: Bronchopneumonia had developed again.

Sixty-ninth day: The lungs were clearing. An abscess of the left groin was opened.

Eighty-third day: The patient was given a transfusion.

One hundred and ninth day: A Reverdin skin graft was made.

One hundred and fortieth day: Epithelialization was complete. The patient was discharged, well (July 17).

Case 12.—*History.*—S. C. Y., a servant, aged 14, admitted March 19, 1923, twenty days before admission "sprained" his ankle. The swelling gradually increased for six days. The surface then became red and hot. A Chinese doctor massaged it and applied some Chinese medicine, without relief. After three days, another doctor applied a yellow ointment, still without relief. Two days later, blisters began to form on the outer side of the foot and the skin turned black. Necrosis rapidly followed, and after three days, the dead skin began to separate, and the patient removed it with scissors. Fever and prostration were marked since the onset.

Physical Examination.—The boy looked desperately ill, and was very toxic and dull. The temperature was 39.2 C. (102.5 F.); pulse, 160; respiration, 28. The outer side of the left ankle presented two, large, ulcerated areas measuring roughly 5 cm. in diameter, one above and one below the external malleolus,

Fig. 15 (Case 12.—Appearance of lesion, fourteenth day of disease and day of admission. The dead skin has sloughed off. The end of the fibula is bare. All of the tarsal joints and the ankle are infected.

which was bare and had been broken off or separated at the epiphyseal line. The ankle and tarsal joints were all suppurating. The bases of the ulcers were covered with slough and the margins were undermined. Redness and swelling extended upward to the knee, gradually fading off into normal tissues. There was an area of cellulitis on the left elbow and another on the chin. The blood count was: white cells, 10,400; polymorphonuclears, 77; red cells, 3,340,000; hemoglobin, 65. A blood culture yielded hemolytic streptococci. The urine showed a very faint trace of albumin. The Wassermann reaction was negative.

Operation.—The toxic condition of the patient and infection of the ankle and foot joints seemed to indicate amputation. The foot was disarticulated at the ankle. The fibula was denuded of its periosteum. Subcutaneous and subperiosteal dissection by pus extended up to the head of the fibula. The muscles were relatively normal. A long external incision was made, with removal of the shaft of the fibula. Cultures showed hemolytic streptococci, hemolytic

Staphylococcus aureus, nonhemolytic straphlococci and an anaerobic organism later reported to be of the *B. welchii* group. Surgical solution of chlorinated soda was applied to the leg with Carrel tubes, and a poultice was applied to the chin and elbow.

Course.—First day: The patient was very much better clinically. The elbow lesion was localizing.

Second day: The muscles of the leg were turning black in spite of wide exposure and irrigation with surgical solution of chlorinated soda.

Third day: The subcutaneous abscess of the elbow region was opened. Culture showed hemolytic streptococci, hemolytic staphylococci and nonhemolytic

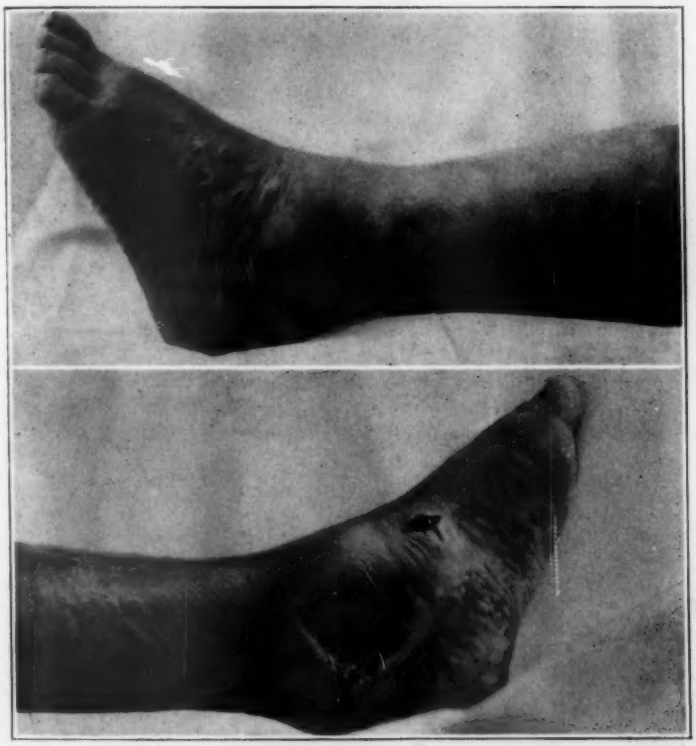

Fig. 16 (Case 13).—Appearance of lesion, fifth day of disease and morning after admission. Above: The early stage of gangrene. Blisters have formed and several of them have broken, discharging dark serous fluid. Below: The inadequate incisions, discharging a dark serous fluid. Necrosis of the subcutaneous tissue is seen. Blisters have formed on the leg.

staphylococci. Necrosis of the leg muscles was progressing. There was no spread of superficial infection.

Fourth day: Large pieces of necrotic muscle were removed. The patient was very toxic.

Fifth day: The patient was toxic and delirious. Amputation of the lower third of the thigh was performed. Death quickly followed the operation.

CASE 13.—*History.*—W. S. F., a soldier, aged 25, admitted, March 19, 1923, twenty days before admission had a corn on his heel cut off. Soreness developed, and he went into an army hospital. Suddenly, four days before admission, the whole foot became red, swollen, hot and tender, and in two days more, redness and swelling spread up to the knee. The third day, the redness spread up above the knee along the internal saphenous vein, and in twenty-four hours it had reached the groin. Two days before admission, the army doctor made two small incisions on the inner side of the foot. Fever and prostration had been marked since the onset, with great pain.

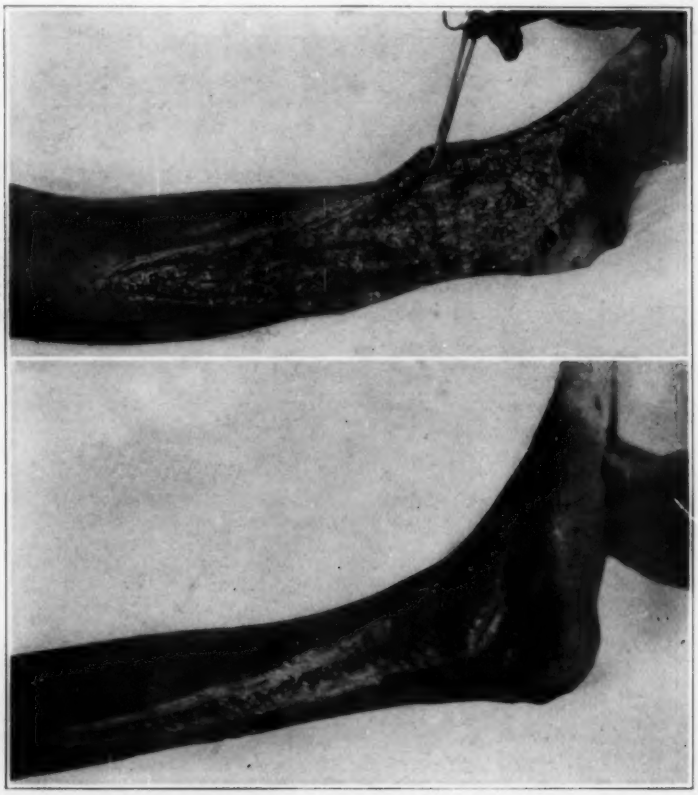

Fig. 17 (Case 13).—Above: Appearance of lesion, ninth day of disease and fourth day after operation. The subcutaneous necrosis had spread both longitudinally and laterally much farther than was anticipated before operation, requiring this extensive incision. Below: Appearance fifty-seventh day of disease, fifty-second day after operation, and ninth day after skin graft, showing the great contraction of the wound. The grafts have become crowded together.

Physical Examination.—The patient was acutely ill, toxic, very anxious and in great pain. The temperature was 39.5 C. (103 F.); pulse, 124; respiration, 26. The left foot and leg were greatly swollen, edematous and red, more on the inner than on the outer side. The redness gradually faded as it approached the knee. There were two, small, gaping incisions on the inner side of the foot,

discharging serosanguineous fluid and revealing a yellowish brown necrosis of the subcutaneous tissue. On the outer side of the foot, there was a large, irregular area of beginning gangrene with a number of broken blisters. On the thigh, there was redness over the course of the internal saphenous vein, particularly marked just above the knee and at the saphenous opening. The blood count was: white cells, 21,000; polymorphonuclears, 83; red cells, 5,380,000; hemoglobin 104 (?). A blood culture was negative. The urine showed a faint trace of albumin. The Wassermann reaction was negative.

Operation.—An incision was made on the inner surface of the leg almost to the knee, to the upper limits of subcutaneous necrosis; another on the outer side of the dorsum of the foot through the gangrenous skin. A culture of pus showed pure hemolytic streptococci. The foot and leg were soaked in hot water Flaxseed poultices were applied to the thigh.

Course.—Second day: A blood culture was positive, showing hemolytic streptococci. Cellulitis was very much less. Soaking was stopped and surgical solution of chlorinated soda was applied.

Third day: Large quantities of subcutaneous and cutaneous slough were removed from the foot.

Fifth day: The groin inflammation was subsiding, but the process was localizing over the vein just above the knee. The wound granulations were active.

Eighth day: A blood culture was negative. The phlebitis was fading.

Tenth day: There was localization of pus around the vein above the knee. An incision was made.

Fourteenth day: There was localization of pus under the skin on the outer surface of the calf. An incision was made.

Forty-third day: A Reverdin skin graft was made, and was entirely successful.

Fifty-seventh day: Epithelialization was complete. The patient was discharged, well (May 21).

CASE 14.—*History.*—F. S. L., a clerk, aged 33, admitted, March 26, 1923, sixteen days before admission fell and struck his leg. A few hours later, he felt a soreness of the leg and on examination found a small red area on the upper third. That night, the leg became red and swollen from foot to knee and upward along the inner side of the thigh. At the same time, he became feverish. The second day, the process advanced upward. The fifth day, an area on the dorsum of the foot became dark, gradually turning black and later greenish yellow. The seventh day, this area broke open and discharged pus. Since then, the process had slowly advanced.

Physical Examination.—The patient looked tired and anxious and was apparently in pain. The temperature was 38.4 C. (101 F.); pulse, 112; respiration, 24. The leg and thigh were greatly swollen and red, particularly on the inner surface. On the inner side of the calf, there was a small necrotic area discharging pus and revealing extensive undermining in all directions. The redness had spread up along the long saphenous vein on the thigh, gradually fading above. The foot presented an irregular area of necrotic skin on the dorsum. It was sharply demarcated from the surrounding skin, but separation had not taken place. The blood count was: white cells, 20,000; polymorphonuclears, 83; red cells, 4,000,000; hemoglobin, 85. A blood culture was negative, as were urine and Wassermann tests.

Operation.—Four incisions were made, one through the area of necrosis on the dorsum of the foot; one behind each malleolus; one on the inner surface of the calf. A culture of pus yielded pure hemolytic streptococci. The leg was soaked in hot water and flaxseed poultices were applied to the thigh.

Course.—Second day: The cellulitis was less. Soaking was stopped and surgical solution of chlorinated soda was applied with Carrel tubes.

Fourth day: Large quantities of slough were removed.

Seventh to thirty-ninth days: There was a general resolution with localization of pus in ten places on the leg and thigh.

Fifty-seventh day: A Reverdin skin graft was made, but the routine was not carefully carried out, so the operation was only partially successful on the foot.

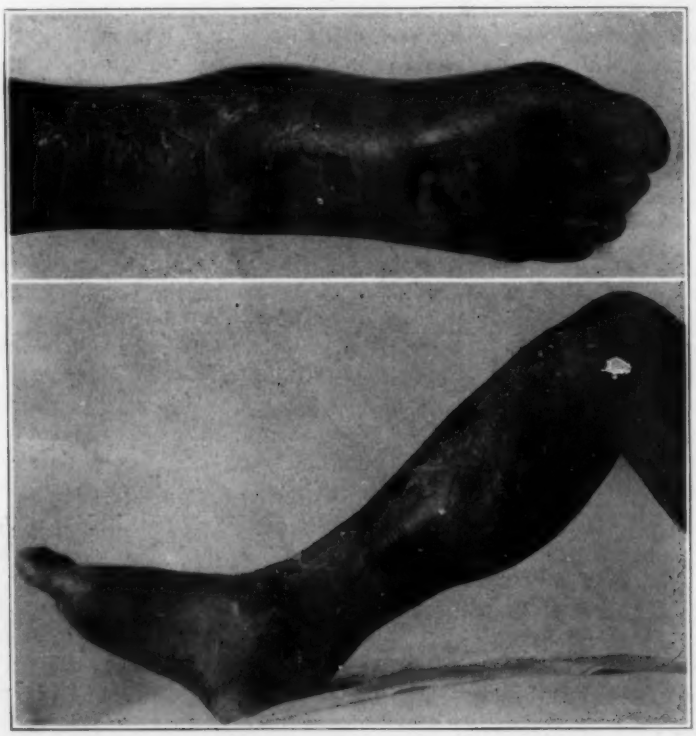

Fig. 18 (Case 14).—Appearance of lesions, seventeenth day of disease and morning after admission. Above: The area of gangrene is of greenish yellow color. The margins are clear cut but separation has not yet taken place (slower than in most of the cases). Below: A very small gangrenous area of skin with extensive subcutaneous slough. The dark area is smooth and shiny but not gangrenous.

Sixthy-seventh day: A Thiersch skin graft was a complete failure as there was too much exudate. The grafts were lifted up.

One hundred and second day: The patient was discharged, July 6. A small area on the calf was still not covered by epithelium, but the margins showed active epithelialization.

CASE 15.—*History.*—W. W., a monk, aged 37, admitted, April 10, 1923, a morphin habitué, seventeen days before admission gave himself a morphin injection in the left forearm just below the elbow. The next day, the redness and swelling spread up and down, and in two days it extended from wrist to shoulder. In six or seven days, the skin became black in several places on the arm and forearm, and he went to a hospital, where two small incisions were made, without arresting the process. Necrosis and general prostration continued to advance.

Physical Examination.—The patient was desperately ill, weak and prostrated. He responded poorly to questioning. The temperature was 38.1 C. (100.6 F.); pulse, 84; respiration, 20. The left upper extremity was greatly swollen and red from shoulder to hand. On the outer surface of the arm and the dorsum of the forearm, there were several irregular areas of skin necrosis, with pus discharging from the separated margins. The inner surface of the arm presented a huge area of necrosis with a number of openings in the center and on the

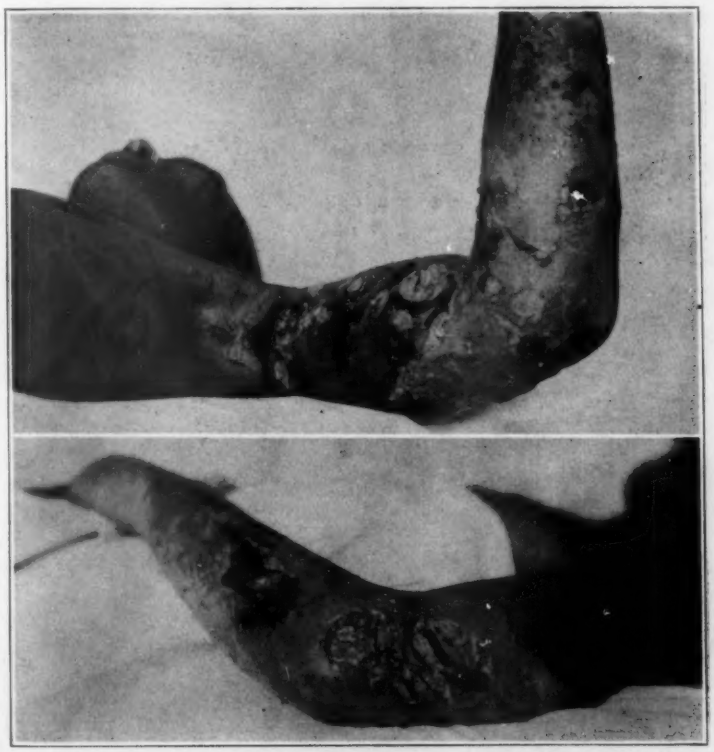

Fig. 19 (Case 15).—Appearance of lesions, seventeenth day of disease, day of admission, illustrating an extensive gangrenous process. Above: Separation of the dead skin at the margins. The line on the chest indicates the margin of erysipelas. Below: Two stages of the gangrenous process. Above the elbow, the dead skin is greenish yellow and separation has begun. On the forearm, the skin is black and has not yet separated.

margins, discharging pus and revealing an extensive necrosis of the subcutaneous tissues. Over the shoulder and in the axilla, the skin was dull red. The margin of this red area was brighter, raised up and sharply demarcated, a very definite erysipelas. The blood count was: white cells, 28,000; polymorphonuclears, 96; red cells, 5,160,000; hemoglobin, 95. A blood culture yielded hemolytic streptococci. The urine reaction was negative, the Wassermann positive.

Operation.—Incisions were made from deltoid insertion to wrist and from axilla to wrist. All of the subcutaneous tissue of the forearm and almost all on the arm was gangrenous. Cultures were taken from the extremities of the

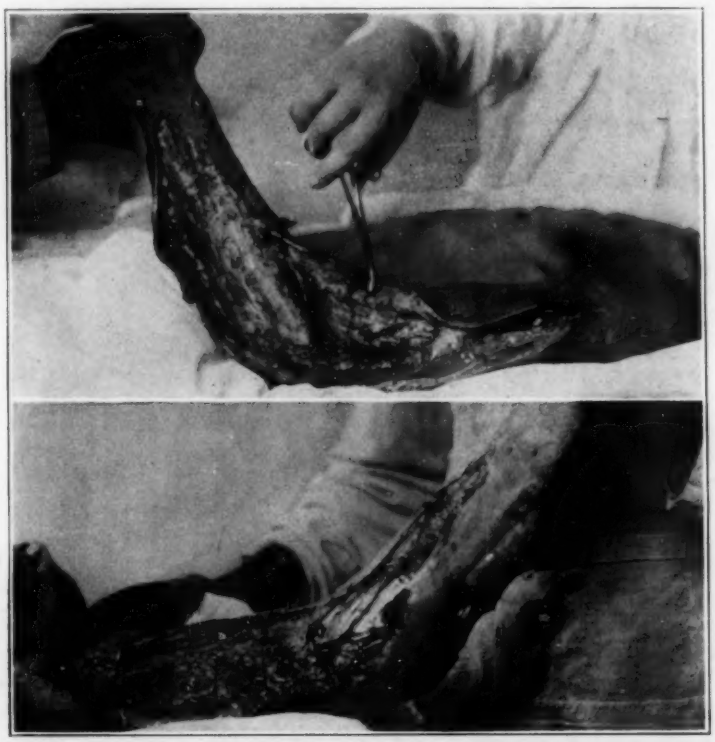

Fig. 20 (Case 15).—Appearance of lesion, twentieth day of disease and third day after operation. Above: The extent of circumferential undermining. The vessels passing from the muscles to the skin on the ulnar side of the forearm were broken during the operation and that skin subsequently sloughed. Below: The extent of the subcutaneous necrosis and the preservation of the long superficial veins.

involved area, and one showed pure hemolytic streptococci. Another showed, in addition, *Staphylococcus aureus.* The third showed both of these organisms and *B. pyocyaneus.* The arm was put in a hot soak.

Course.—First day: Sceleth's treatment was employed, but it did not control the pain and seemed to precipitate delirium.

Third day: The delirium was worse. There was incontinency of urine. Beginning erysipelas of the cheek was noted. The temperature was 39.6 C. (103.3 F.). Sceleth's mixture was stopped and straight morphin was given.

Fourth day: The patient was quiet and rational at times. The skin on the forearm between the incisions had become gangrenous. The other sloughs were separating. The arm and forearm resembled those subjected to anatomic dissection. There was no evidence of healing.

Sixth day: The temperature was still high, 40 C. (104 F). The erysipelas was fading in the axilla, but was spreading over the face, closing the right eye.

Seventh day: The erysipelas of the face was fading.

Fifteenth day: A blood culture was positive. A bed sore was developing over the sacrum and the right heel and ankle.

Nineteenth to twenty-sixth days: There were large, subcutaneous localizations of pus of the right foot, leg and thigh and the right side of the neck. The arm was clean. All slough was separated, but there was no evidence of healing. The asthenia was progressing. There were no chest signs.

Twenty-seventh day: The heart rather suddenly failed, and the patient died in a few hours. A blood culture was positive. There was no necropsy.

Case 16.—*History.*—L. P. Y., a clerk, aged 23, admitted, April 30, 1923, seven days before admission scratched the dorsal surface of forearm, which itched. The next day there was redness and swelling, which spread rapidly to the shoulder. No advancing red margin was noticed. The second day, the patient went to a Chinese physician trained abroad, who applied some white paste. Swelling continued and the pain became severe. The third day, a small incision was made on the back of the forearm. The fifth day, the skin became black, and in twenty-four hours it had separated in several places and was discharging pus. There were chills and vomiting on the first day, with continued fever and progressive prostration up to the time of admission.

Physical Examination.—The patient looked acutely ill, and was apparently in great pain, tired and prostrated. The temperature was 37.9 C. (100.2 F.); pulse, 122; respiration, 25. The whole, left upper extremity was extremely swollen from wrist to shoulder. On the inner surface of the arm, there was a large irregular area of yellowish black necrotic skin, separating at the margins. From beneath it, pus and slough were discharging. The skin on the volar surface of the forearm was dusky, in a state of early necrosis, with blistering of the surface. On the back of the forearm, there was a small incision, revealing a necrosis of the subcutaneous tissue. The surrounding skin looked as if it had been burned. The blood count was: white cells, 76,000; polymorphonuclears, 90; red cells, 4,320,000; hemoglobin, 67. A blood culture was negative. The urine showed a heavy trace of albumin. The Wassermann reaction was negative.

Operation.—Incisions were made from axilla to wrist on the volar surface of forearm to the limits of the undermined area. On the back of the forearm, the previous incision was enlarged. The arm was put in a hot soak. A culture of pus showed pure hemolytic streptococci.

Course.—First day: The white blood cells numbered 42,500; the polymorphonuclears, 87.

Second day: The cellulitis had largely disappeared. Soaking was stopped and surgical solution of chlorinated soda applied with Carrel tubes.

Fourth day: The slough was separating rapidly. A blood culture was negative.

Eighth day: Most of the slough separated, but the margins were still undermined. A blood culture was negative.

Twenty-third day: The margins were adherent except at one point, where there was undermining connecting the dorsal and ventral incisions. The bridge was cut to get better antiseptic contact.

Fortieth day: A Reverdin skin graft was made. Routine treatment was not followed, and the grafts were allowed to dry over night. Superficial necrosis of the grafts occurred, although some cells from most of the grafts survived.

Fifty-fifth day: The wound was greatly contracted. The epithelium was active, but had not completely covered the area.

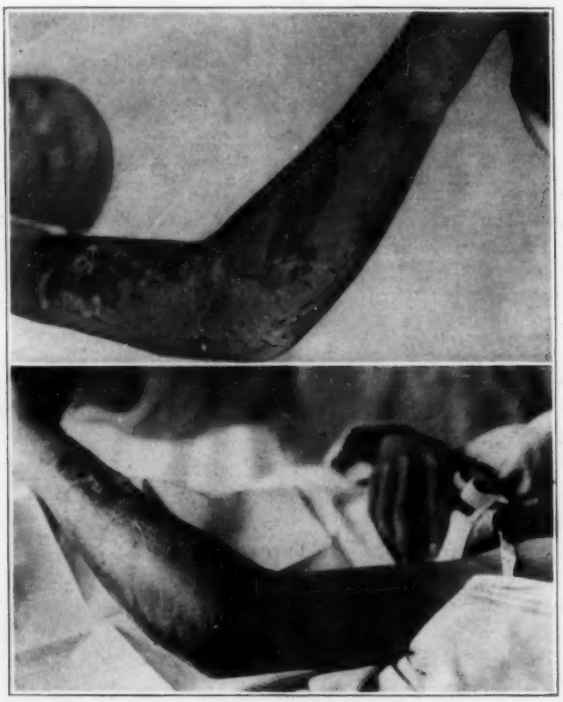

Fig. 21 (Case 16).—Appearance of lesion, seventh day of disease and day of admission. Above: The large area of dead skin on the arm beginning to separate. The black areas on the forearm are still in continuity with the relatively normal skin. Below: The dorsum of the forearm, which appears to have been extensively burned.

Seventy-third day: There was complete epithelialization, and the patient was discharged (June 24).

Case 17.—L. C. K., a soldier, aged 23, admitted April 30, 1923, thirteen days before admission played foot ball. He did not know whether or not he injured his leg at that time, but he associated his present illness with the game. Two or three days later, the left leg began to swell, with pain above the ankle, and he had a chill, followed by fever. He went into the army hospital where the leg was soaked in hot water. The next day, it became red and swollen up to

the knee. Soaking was continued. The fifth day, a large area on the front of the leg became black. Soaking was continued, and on the eighth day, the slough separated and came off.

Physical Examination.—The patient looked weak, pale and tired. The temperature was 38 C. (100.4 F); pulse, 87; respiration, 22. A large ulcerated area on the middle of the front of the leg, with actively granulating base, was covered with pus and small pieces of slough. The skin was undermined on all sides by a necrosis of the subcutaneous fat. There was a smaller ulcer just above the ankle and several smaller holes which communicated beneath the skin with each other and with the larger ulcers. Posteriorly, there were redness and swelling, but no undermining. The redness and swelling gradually faded off above. The blood count was: white cells, 19,200; polymorphonuclears,

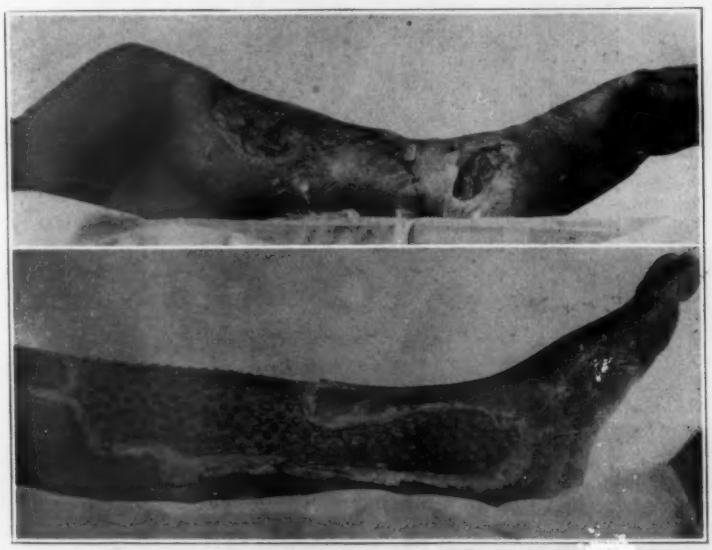

Fig. 22 (Case 17).—Above: Appearance of lesion, fourteenth day of disease and morning after admission, illustrating the extent of the subcutaneous necrosis and the rapid separation of the dead skin in certain cases. Below: appearance, forty-first day of disease, twenty-seventh day after operation and third day after skin graft. All of the grafts have become adherent except a few near the posterior margin above the ankle. At this point, the skin was still slightly undermined.

82; red cells, 5,600,000; hemoglobin, 89. A blood culture was negative, as were urine and Wassermann tests.

Operation.—Incisions were made above the main ulcer to the limits of the undermined skin on either side of the tibial tubercle. Below, an incision was made connecting the ulcers and extending down to the inner side of the foot. The leg was put in a hot water soak. The temperature ranged from 40 to 42 C. (104 to 107.6 F). A culture of pus from the foot yielded pure hemolytic streptococci. The leg ulcer also showed a gram-positive and a gram-negative bacillus, unidentified.

Course.—Second day: The cellulitis was much less. Soaking was stopped.

Sixth day: Large pieces of slough separated. Granulations were active. The undermined edges were becoming adherent.

Sixteenth day: A small lateral pocket was opened in order to effect a better antiseptic contact.

Twenty-fifth day: The wound was contracting nicely. The epithelium was active on all margins except at one point where there was slight undermining and discharge of pus. A Reverdin skin graft was made. Ten small grafts were lost near the region of the undermined skin.

Forty-first day: Epithelialization was complete, and the patient was discharged (July 7).

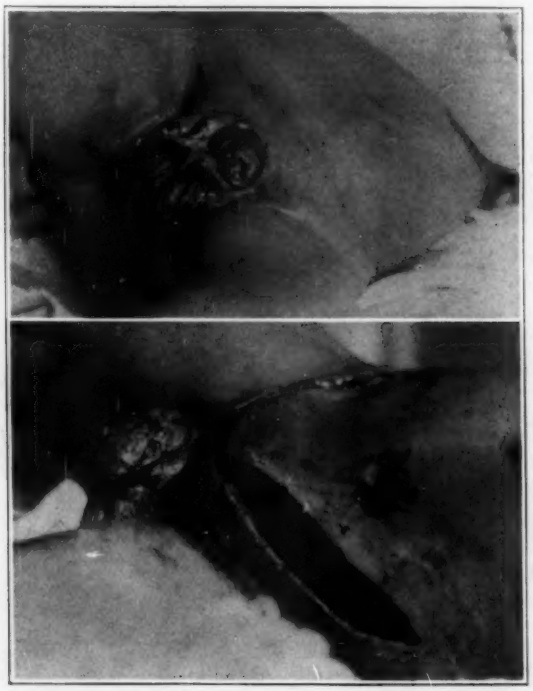

Fig. 23 (Case 18).—Above: Appearance of lesion, tenth day of disease and day of admission, showing complete gangrene of the scrotum and the distal half of the skin of the penis. The thighs are excoriated. The lower abdomen is discolored. Below: Appearance, eleventh day of disease and day after admission, showing the extent of the subcutaneous necrosis in the abdominal wall, which was even more extensive on the right side than on the left.

Case 18.—*History.*—C. P. C., a merchant, aged 50, admitted, May 22, 1923, ten days before admission had a sense of discomfort in the scrotum and lower abdomen. He felt sick and lost his appetite. The next day, the scrotum itched and he scratched it. Thereafter, he became feverish and greatly prostrated, and was confined to bed. The swelling rapidly spread to the penis and lower abdomen. The fifth day, the skin of the scrotum and penis became black. Two days later, it began to separate at the margins and discharged pus. Urination was normal.

Physical Examination.—The patient looked acutely ill, greatly prostrated and dull, but was not in severe pain. The temperature was normal; pulse 102; respiration, 20. The scrotum, which was entirely gangrenous, hung down as a black bag between the thighs, which were excoriated where it was in contact. The skin of the distal half of the penis was likewise affected. The dead skin had separated at the margins and revealed an extensive subcutaneous necrosis. The glans was not affected. The abdomen below the umbilicus was red, indurated and edematous, with the upper limits gradually fading off into normal skin. Over the right inguinal region, the skin was dusky, and beneath it a softening of the subcutaneous tissues could be felt. The blood count was: white cells, 21,500; polymorphonuclears, 90; red cells, 4,900,000; hemoglobin, 75. A blood culture was negative. The urine showed a faint trace of albumin. The Wassermann reaction was negative.

Operation.—Incisions were made over both inguinal regions, revealing an extensive necrosis of the subcutaneous tissues, particularly on the right side.

Fig. 24 (Case 19).—Appearance of lesion, ninth day of disease and morning after admission, illustrating the early appearance of spreading gangrene with blister formation and discoloration as in an extensive burn. The whole right side of the chest is involved.

The gangrenous skin of the penis and scrotum were lifted off like a cap, leaving the glans and testicles bare. The wounds were packed open, and later, irrigation was made with surgical solution of chlorinated soda. A flaxseed poultice was employed for cellulitis of the abdomen. Fluid was given by rectum. A culture of pus from the left inguinal wound yielded pure hemolytic streptococci. In the other wounds, hemolytic streptococci predominated. A few colonies of hemolytic *Staphylococcus aureus* were found.

Course.—First day: Large quantities of subcutaneous slough were removed from the right abdominal wound. The involvement was all superficial to the external oblique aponeurosis, communicating along both cords to the scrotal wound.

Second day: The cellulitis of the abdominal wall was receding.

Sixth day: The slough had all separated. Granulations were very active.

Eighteenth day: The undermining margins were becoming adherent, and the testicles were contracting.

Twenty-seventh day: A Reverdin skin graft was made to the inguinal wounds and testicles. Three or four were lost on the testicles. All lived on the inguinal wounds except a few on the right side near the undermined skin.

Forty-fourth day: The patient was discharged (July 5). Small areas in the right inguinal wound and on the right testicle were not yet covered with epithelium.

Case 19.—*History.*—Y. W. C., a soldier, admitted, July 11, 1923, eight days before admission developed a small boil on the right side of the chest, very red and exquisitely painful. The next day, the redness and swelling spread very rapidly in all directions, with high fever and great prostration. The sixth day, the skin began to turn dark. An army doctor made a small incision over the site of the original lesion, but the whole process developed rapidly.

Physical Examination.—The patient was extremely ill. His face was ashen with cold sweat. The respiration was very rapid and shallow; the radial pulse was not palpable. The temperature was 38.2 C. (100.7 F.); pulse, 160; respiration 38. Over all the right side of the trunk, there was great swelling, redness and edema, extending from the shoulder and axilla down to the crest of the ileum and from just to the right of the midline in front to a corresponding region behind. The margins faded off into normal tissues. In the midaxillary line, there was a small incision, 5 cm. in length, revealing a necrosis of the subcutaneous fat. Around this and particularly anterior to it, the skin was blue, in a stage of early necrosis. No crepitation was present. The blood count was: white cells, 21,000; polymorphonuclears, 90; hemoglobin, 95. A blood culture was negative. Urine tests were negative.

Fig. 25 (Case 20).—Appearance of lesion, fourth day of disease and day of admission. The gangrenous skin becomes black early with blisters forming higher up.

Treatment.—The patient was considered too ill for operation. Flaxseed poultices were applied locally. Fluid was given by rectum. Cardiac stimulants were employed.

Course.—Second day: The gangrene had spread extensively in all directions, but there was no extension of redness and swelling. The general condition was about the same. Under ethyl chlorid anesthesia (local), a single, long incision was made through the necrotic and necrosing skin, revealing extensive necrosis

Fig. 26.—Photomicrograph (× 75) showing a partial occlusion of the lumen of one of the subcutaneous vessels by a new growth of young connective tissue from the intima on one side. The rest of the lumen is filled with degenerated blood and pus cells (hematoxylin and eosin).

Fig. 27.—Photomicrograph (× 650), oil immersion lens; showing streptococci in and among the broken down cells in the lumen of the vessel (Macallum stain for bacteria in tissues).

TABLE 1.—*Summary of Cases*

			History						Physical Examination											
Case	Sex*	Age, Years	Initial Lesion	Location	Days Before Gangrene Developed	Fever	Prostration	Previous Application of Medicine	Parts Involved	Gangrene	Subcutaneous Necrosis	Cellulitis	Lymphangitis	Lymphadenitis	Phlebitis	Erysipelas on Admission	Erysipelas after Admission	Temperature on Admission, C.	Pulse Rate on Admission	Respiration Rate on Admission	Acutely Ill on Admission
1	♂	30	Boil	Foot	4	+	+	—	Foot	+											
									Leg	+	+	+	—	+	—	—	—	38.2	112	22	+
2	♂	61	Lacerated wound	Hand	4	+	+	—	Hand	+											
									Forearm	+	+	+	—	+	+	—	—	36.6	90	24	+
3	♂	40	From hypodermic needle	Forearm	4	+	+	—	Forearm	+	+	+	—	—	—	—	—	37.6	84	17	+
4	♂	30	Boil	Leg	?	+	+	—	Foot	+											
									Leg	+											
									Thigh	+	+	+	—	—	—	—	—	33	102	22	+
5	♂	32	Ulcer	Foot	?	+	+	—	Foot	+											
									Leg	+	+	+	—	—	—	—	—	38.2	94	20	+
6	♀	32	None	Arm	4–5	+	+	+	Arm	+	+	+	—	+	—	—	+	39.6	124	26	+
7	♂	80	Boil	Forearm	5–7	+	+	—	Forearm	+	+	+	—	—	—	—	—	37.4	72	24	±
8	♂	44	None	Thigh	2–4	+	+	—	Thigh	+	+	+	—	—	—	—	2+	38.7	96	24	+
9	♂	35	Boil	Arm	5	+	+	—	Arm	+											
									Forearm	+	+	+	—	—	—	—	—	37	88	22	+
10	♂	54	Compound fracture	Wrist	3	+	+	+	Hand	+											
									Forearm	+											
									Arm	+	+	+	—	—	—	—	—	35	120	30	+
11	♀	17	Frostbite	Foot	4	+	+	+	Foot	+											
									Leg	+	+	+	—	+	—	—	—	37.3	144	32	+
12	♂	14	Compound fracture	Foot	5	+	+	+	Foot	+											
									Leg	+	+	+	—	—	—	—	—	39.2	100	28	+
13	♂	25	Corn	Foot	5	+	+	—	Foot	+											
									Leg	+	+	+	—	—	+	—	—	39.5	124	26	+
14	♂	33	Abrasion	Leg	5	+	+	—	Foot	+											
									Leg	+	+	+	—	—	+	—	—	38.2	112	24	+
15	♂	37	From hypodermic needle	Arm	6–7	+	+	—	Arm	+											
									Forearm	+	+	+	—	—	—	+	+	38.1	84	20	+
16	♂	23	Scratch	Forearm	5	+	+	+	Forearm	+											
									Arm	+	+	+	—	—	—	—	—	37.9	122	25	+
17	♂	23	None	Leg	5	+	+	—	Leg	+	+	+	—	—	—	—	—	38	87	22	+
									Foot	+											
18	♂	50	Scratch	Scrotum	5	+	+	—	Scrotum	+											
									Penis	+											
									Abdomen	—	+	+	—	—	—	—	—	37	102	20	+
19	♂	23	Boil	Chest	6	+	+	—	Chest	+											
									Abdomen	+	+	+	—	—	—	—	—	38.2	100	38	+
20	♂	17	Lacerated wound	Foot	4	—	—	—	Foot	+	+	+	—	—	—	—	—	37.4	96	20	±

* In this column, ♀ represents female, ♂, male.

TABLE 2.—*Summary of Cases*

	Laboratory Findings											Clinical Course							
Case	White Blood Cells on Admission	Polymorphonuclears, per Cent.	Red Blood Cells on Admission	Hemoglobin	Blood Culture on Admission	Blood Culture Later	Albuminuria	Wassermann	Hemolytic Streptococci in Lesion	Pure Hemolytic Streptococci in at Least 1 Wound	Contamination	Secondary Localization	Metastases	Day of Disease on Admission	Day of Disease Operated On	Day of Disease Skin Grafted	Day of Disease Died	Day of Disease Completely Epithelialized	Day of Disease Discharged
1	6,460	..	.....	..	..	+	—	..	+	—	+	—	—	4	8	—	—	—	15
2	14,400	82	.....	..	—	..	—	..	+	+	—	—	+	4	6	24	—	54	55
3	18,300	72	.....	..	..	..	+	..	+	+	—	—	..	6	6	20	—	50+	46
4	16,000	..	.....	..	..	..	+	..	+	+	—	+	..	14	14	63	—	90+	58
5	10,500	..	.....	..	+	..	—	..	+	+	—	+	..	14	14	—	—	—	47
6	14,800	69	4,800,000	88	..	—	—	..	+	+	—	+	—	7	7	27	—	28	39
7	8,500	80	4,200,000	80	—	..	+	—	+	+	—	—	—	15	..	26	—	137	48
8	19,850	89	.....	..	—	2 —	—	+	+	+	—	—	..	15	15	51	—	86	86
9	12,000	67	4,100,000	90	..	..	..	—	+	—	+	+	—	23	27	59	—	83	83
10	14,400	91	3,800,000	100?	+	3 +	—	—	+	—	+	+	+	5	5	—	22	—	—
11	16,700	80	3,780,000	60	—	1 +, 3 —	+	—	+	+	+	+	+	15	15	124	..	143	165
12	10,400	77	3,340,000	65	+	..	+	—	+	—	+	+	+	14	14	—	19	—	—
13	21,000	83	5,380,000	104?	—	1 +, 1 —	+	—	+	+	—	+	—	4	5	48	—	62	62
14	20,000	83	4,000,000	85	—	—	—	—	+	+	—	+	—	16	16	73	..	128	118
15	28,000	95	5,160,000	95	+	8 +	—	+	+	+	+	+	+	17	17	—	44	—	—
16	76,000	90	4,320,000	67	—	3 —	+	—	+	+	—	+	—	7	7	47	—	80	64
17	19,200	82	5,600,000	80	—	..	—	—	+	+	+	+	—	13	13	38	—	54	54
18	21,500	90	4,900,000	75	—	—	+	—	+	+	+	+	—	10	10	39	..	70+	55
19	21,000	90	.....	95	—	..	—	..	+	—	+	+	—	8	9	—	9	—	—
20	18,000	87	4,700,000	75	..	..	—	—	+	+	—	—	—	4	4	38	—	50+	49

of the subcutaneous fat. There was only slight bleeding, but large quantities of serosanguinous fluid poured out. Poultices and stimulants were renewed. The patient died one hour after operation (July 12). Culture of the pus gave many colonies of hemolytic streptococcus and a few colonies of *Staphylococcus albus*.

CASE 20.—L. C., an apprentice, aged 17, admitted, June 12, 1923, four days before admission suffered the loss of all of the toes of the left foot, which were cut off by a railroad car. The next day, the foot began to swell. The second day, the swelling spread up to the ankle. The third day, the affected area became very red. On the day of admission, the patient noticed for the first time that the skin had become black over the dorsum of the foot. There was no fever and very little prostration.

Physical Examination.—The patient looked acutely ill, and had a tired, anxious, pained expression. The temperature was 37.4 C. (99.3 F.); pulse, 96; respiration, 20. The distal phalanges of all the toes of the left foot had been traumatically amputated, and the stumps were left covered with old blood and dirt. Some sutures had been taken over the stump of the little toe. The whole foot was greatly swollen and moderately red. The upper margin of redness faded off gradually at the ankle. On the outer side of the dorsum of the foot, the skin was dark purple, with blisters and bullae on the surface above the dead skin. A blood culture was not taken before operation. Urine and Wassermann tests were negative.

Operation.—An incision was made from in front of the outer malleolus down to the web between the third and fourth toes, revealing a subcutaneous necrosis over the outer two thirds of the foot. The necrotic tissue was fairly easily separated, with little bleeding. A culture of pus yielded pure hemolytic streptococci. The foot was put in a hot water soak.

Course.—First day: The cellulitus was much less.

Second day: A considerable amount of slough was cut off. Soaking was stopped, and surgical solution of chlorinated soda was applied with compresses.

Third day: The temperature was normal. The slough was separating rapidly.

Eighth day: The slough had all separated. Granulations were active. A blood culture was negative.

Twenty-seventh day: About half of the margin was still undermined. The rest showed new epithelium.

Thirty-first day: The margin all showed active epithelium except at one place near the ankle. A skin graft was made. About ten grafts near the undermined margin failed to live.

Fortieth day: The wound was contracting, and slowly and gradually becoming epithelialized.

Forty-ninth day: Almost complete epithelialization resulted. The patient was discharged (July 31).

REACTION OF BONE TO VARIOUS METALS*

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HISTORICAL REVIEW

Early in the history of surgery, when surgeons were more concerned with the closure of wounds than in their making, metal was being implanted in the tissues. Fabricius,[1] in 1647, wrote at length on the use of iron wire sutures, limiting their use, however, to the soft parts. Surviving the blind progress of the times, iron wire is again memorialized by Icart,[2] who in 1775 cut down on a fractured bone and approximated the ends by suture. Laloy[3] also relates the practice of wire suture by Flaubert of Rouen, and the literature of the period records various similar reports. It remained for Levert[4] to make the first deliberate inquiry into the method, and in 1829 he performed a rather extended series of experiments on dogs to determine the tolerance to metallic sutures, using gold, silver, lead and platinum. The last he found to be the least irritating. From this time until that of Lister[5] and the advent of a new surgery, the literature merely records the dull comment of a few ambitious but unoriginal workers in this particular field.

With the coming of antisepsis and, later, asepsis, improvement was rapid. Lister had successfully employed buried silver wire sutures for fracture, and Kittredge[6] and Wolff[7] were using metal rivets in bone. Late in the nineteenth century, Lane[8] had been using wire and screws with varying success and was on his way to perfect the fixation of fractures by means of steel plates, which he reported in 1905. In the same decade, Steinbach[9] had employed silver plates and galvanized iron screws with varying success; while Lambotte[10] reported good results with brass plates and copper and iron wire. From this ground-

* From the Department of Surgery, University of Minnesota.

1. Fabricius: De Chirurgicis Operationibus, 1647, p. 146.
2. Icart: J. de Med., Chir. et Phar. de Roux **44**:170, 1775.
3. Laloy: De la suture des os applique aux resections et aux fractures avec plaies, Thèse de Paris, 1839, p. 11.
4. Levert: Am. J. M. Sc. **4**:17, 1829.
5. Lister: Brit. M. J. **2**:855, 1883.
6. Kittredge: Boston M. & S. J. **10**:19, 1891.
7. Wolff: Boston M. & S. J. **10**:20, 1891.
8. Lane: Lancet, 1905.
9. Steinbach: Ann. Surg. **31**:436, 1900.
10. Lambotte: Brit. M. J. **2**:1530, 1912.

work, but chiefly by reason of the ardent championing of Lane,[8] there arose the tremendous vogue of the buried metal plate; a vogue perhaps more notable in this country than abroad.

It has been the observation of medical historians that the life cycle of an idea is predetermined; it arises first on a wave of enthusiasm, only to sink into obscurity, from which it is rescued by some rational individual who recognizes its limitations and puts it to its proper use.

Naturally, then, the first reports, such as Sampson's,[11] who recorded an unbroken series of 104 successes, were invariably favorable, and surgeons good and bad proceeded to insure their future employment by burying metallic substances in some form. The reaction swiftly followed, and soon authoritative voices were raised in the already growing doubt of the propriety of treating fractures in this manner. Once well begun, the controversy elicited a variety of opinions and data. John B. Murphy,[12] always an unbiased observer, remarked on the frequency of nonunion as compared with the preoperative period. Others, notably Albee,[13] Hessert,[14] Lexer[15] and Brickner[16] maintained that buried metal pieces not only failed in fixation but also were noxious to the tissues involved and inhibited their regeneration;[17] while Hallopeau,[18] Dujarier,[19] Fredet[20] and Alglave[21] proclaimed them not only harmless and well tolerated, but actually agents for good. More recently, a few have attempted to verify these clinical observations by experimental means. Trout[22] inserted steel screws into bones of young rabbits and noted an arrest in bone growth, and Albee[23] in another paper presented similar conclusions but from rather inadequate material. Stanley and Gatellier,[24] in an extended article with considerable clinical and roentgen-ray evidence, developed some points of considerable value, as their work was almost entirely concerned with the Parham band. Their observations were that, in contact with the band, early ossification was delayed, but that no necrosis was discernible, nor was

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11. Sampson: Lancet **183**:433, 1912.
12. Murphy, J. B.: Surgical Clinics **3**:1003.
13. Albee, F. H.: Am. J. Surg. **28**:20, 1914.
14. Hessert: Surg., Gynec. & Obst. **13**:201, 1911.
15. Lexer: Deutsche Ztschr. f. Chir. **133**:170, 1915.
16. Brickner: Am. J. Surg. **28**:16, 1914.
17. Lexer: Zentralb. f. Chir. **42**:217, 1915.
18. Hallopeau: Bull. et. mém. Soc. de chir. de Paris **46**:879, 1920.
19. Dujarier: Bull. et mém. Soc. de chir. de Paris **46**:990, 1920.
20. Fredet: Bull. et mém. Soc. de chir. de Paris **46**:992, 1920.
21. Alglave: Bull. et mém. Soc. de chir. de Paris **46**:1083, 1920.
22. Trout: Ann. Surg. **61**:717, 1915.
23. Albee, F. H.: Orthopedic and Reconstructional Surgery, Philadelphia, W. B. Saunders, 1919.
24 Stanley, E. G., and Gatellier, J.: Brit. J. Surg. **9**:259 (Oct.) 1921.

there any evidence of oxidation or of the toxic action of iron salts. Leriche and Policard,[25] by histologic examination and chemical analysis of the tissues involved, determined that not only was the bone adjacent to a buried steel plate necrotic and rarefied, but that there likewise occurred a marked impregnation of the underlying structure with iron salts.

Mann [26] carried out a short series of experiments on dogs to determine the tolerance of joints to steel nails and screws, finding them well imbedded at four weeks, and the surrounding bone showing only a slight rarefaction. But by far the major research was performed by Hey Groves.[27] To arrive at the comparative merits of the various methods of fixation of fractures, he employed a large series of experimental animals over a considerable period of time and planted various metals in the form of plates, ferrules and intramedullary pegs. His conclusions, based on macroscopic observations, are: 1. Nickel-plated steel has no irritating effect on tissues. 2. Magnesium is rapidly absorbed and acts as a powerful stimulant to bone formation. 3. Indifferent aseptic foreign bodies are readily tolerated by the tissues.

PURPOSE OF RESEARCH

From the foregoing, it may be seen that much of the research, while primarily aimed at an evaluation of fracture prosthesis, has not been systematically conducted. There has been sufficient observation of end-results, but the lack of uniformity of material makes analysis difficult, and this same lack of uniformity and absence of accurate controls detracts from the value of the experimental data. In determining the merits of a given procedure, it seems only logical to examine closely the materials employed and to ascertain the degree to which their inherent qualities will modify their utility.

The object of the following research is to determine whether metal per se, when implanted in bone, exerts an influence other than that of any foreign body, and if so, whether this is a property common to many metals or varying with each individual.

To attain this within reasonable limits of error, it is obvious that modifying factors must be rigidly excluded. To this end, mature dogs have been employed as the most suitable laboratory animals, and in each series an effort was made to use animals of the same size and condition.

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25. Leriche and Policard: Bull. et mém. de Soc. de chir. Paris **44**:1145, 1918.

26. Mann, A. T.: Nails and Screws in Fractures, J. A. M. A. **67**:1148 (Oct. 14) 1916.

27. Groves, E. W. H.: Brit. J. Surg. **50**:43, 1913.

To make the data more comprehensive and to observe the reactions of different types and structures of bone, the experiments included the skull, tibia and ribs, the observation time ranging from two to six weeks in the different series.

In order to obtain a bony defect wherein to place a metal implant unaffected by pressure or mobility, holes were drilled in the various parts, and metal plates of the exact depth and diameter were inserted. This was varied somewhat in the skull and ribs as will be noted later in the operative record, but with the intent before mentioned in mind. Aseptic procedure necessarily obtained throughout and was checked by culture and smear at necropsy, the infected specimens being rejected. Although wound hemostasis was uniform and easily obtained, medullary bleeding was a variable factor and a few animals were excluded from the records because of large hematomas.

After considerable experimentation with fixatives and tissue stains, it was found that decalcification was most uniform and rapid with 5 per cent. nitric acid, and that preliminary fixation in 10 per cent. solution of liquor formaldehydi was adequate for the stains required. With hematoxylin and eosin, it was possible to differentiate the structures quite as well as with the special stains, although van Gieson's was employed routinely to emphasize the connective tissue changes, and Mallory's hemosiderin stain was used to delineate the iron pigment. Some difficulty was experienced in obtaining thin sections intact and finally 15 micron celloidin sections were cut for orientation and thinner fragments for detailed study.

MATERIAL AND METHODS

The following catalogue includes the details of the operative procedure. Under ether, six series of mature normal dogs were operated on, with the usual surgical aseptic precautions.

Series I. Ten dogs: Preliminary: to rectify technical procedure and determine optimum time of obtaining specimens.

Series II. Fifteen dogs: The middle third of the tibia was exposed through a 7.5 cm. incision and a 5 mm. hole was drilled through the cortex. A metal implant 5 by 8 by 0.5 mm. was inserted in the hole, flush with the surface of the bone and fitting exactly but without pressure. The overlying fascia was closed with 00 catgut and the skin was closed with interrupted linen sutures. No dressing was applied. In the control animals, the wound was closed after drilling of the bone, without the implantation of a metal. In the remainder the following metals were implanted: gold, silver, aluminum, zinc, lead, copper, nickel, high carbon steel, low carbon steel, stellite, copper aluminum alloy, magnesium and iron.

At the end of six weeks, the dogs were killed, and the tibiae removed and sectioned with a fine saw, under running water. The metal implants were withdrawn from the cut end of the bone and region of the implant cut (as before) into 2 mm. cross sections. These sections were fixed in liquor formaldehydi for five days, then washed and placed in 5 per cent. nitric acid until decalcified, the solution being changed daily. After being imbedded in celloidin, sections were cut and stained.

Series III. Fifteen dogs: The knee joint was exposed by a 7.5 cm. skin incision, parallel to the long axis of the leg, and the joint cavity was opened by a 5 cm. lateral incision. The patella was dislocated medially and the condyle of the femur exposed by flexion of the knee. A hole 2 mm. in diameter and 3 cm. deep was drilled directly in the long axis of the femur and a metal implant 2 mm. by 3 cm. inserted flush with the articular cartilage.

The patella was then replaced and the joint capsule closed with linen sutures. The skin was closed with interrupted linen sutures. In the controls no implants were made. In the experimental animals the following metals were implanted: silver, gold, aluminum, zinc, lead, copper, nickel, high carbon steel, low carbon steel, stellite, copper aluminum alloy, magnesium and iron. At the end of two weeks, the animals were killed and the femora removed. The metals were removed and the region of the implant cut with a fine saw into 2 mm. cross sections. These sections were fixed for five days in 10 per cent. solution of liquor formaldehydi, then removed, washed and placed in 5 per cent. nitric acid, and allowed to decalcify. Later, after being imbedded in celloidin, sections were cut and stained.

Series IV. Four dogs: A 15 cm. skin incision exposed the lower ribs in the axillary line. The superficial fascia and musculature were divided and the midportion of the sixth, seventh, eighth and ninth ribs was exposed. A 2 mm. hole was drilled through the cortex of each rib and metal implants 2 by 4 by 0.5 mm. were inserted, flush with the surface of the rib. Overlying muscle and fascia were closed with No. 2 plain catgut, and the skin was closed with interrupted linen sutures. At the end of four weeks, the animals were killed and the ribs removed. At necropsy, it was found that the rib, because of its size and structure, was not suitable for this type of implant and that the factor of error due to mobility, fracture and operative trauma was so great as to make the results valueless. Gross observations only were recorded.

Series V. Fifteen dogs: A skin incision was made over the midtemporal region extending from the saggittal suture for 5 cm. The underlying temporal fascia was incised in the same line and the muscle retracted to expose an area on the skull about 2 cm. in

diameter. A button of bone 1.5 cm. in diameter was removed with a trephine and the dura exposed. A metal disk exactly filling the opening was inserted, and the deep temporal fascia and pericranium were closed with interrupted 00 chromic catgut. The outer temporal fascia was closed with interrupted linen sutures, as was the skin. The following metals were implanted: silver, gold, aluminum, zinc, lead, copper, nickel, high carbon steel, low carbon steel, stellite, copper aluminum alloy, magnesium and iron. At the end of six weeks suitable portions of the crania were removed for observation.

Series VI. Four dogs: A 15 cm. skin incision in the axillary line and incision of the underlying, superficial musculature exposed the fifth, sixth, seventh, eighth and ninth ribs. The periosteum was incised in the long axis of the ribs for a distance of 3 cm. With a periosteal elevator, the periosteum was loosened from the upper half of the rib and retractors were inserted. With sharp chisels, a section of the upper border of the rib was removed, 1.5 by 0.5 by 0.5 cm., and a metal implant inserted in such manner as to have its ends buried in the medullary bone substance. The usual controls and metals were implanted. The periosteum was closed with 00 chromic catgut and the overlying tissue closed with plain catgut. The skin was closed with interrupted linen sutures.

At the end of four weeks, the desired ribs were removed and roentgenograms taken.

ANIMAL EXPERIMENTATION

Series I. Tibia; six weeks.

Control.—There was a slight amount of scar tissue over the wound. The periosteum was continuous over a slightly raised fusiform protuberance. There was no evidence of infection.

Gold.—There was no inflammatory reaction. There was a slight amount of scar tissue over the bone. A slight fusiform protuberance over the implant was perceptible as a slight bulge. The periosteum was continuous over the implant.

Zinc.—There was a moderate amount of scar tissue overlying the implant area, and muddy discoloration of the soft tissue for an area of 1 cm. There was a slight protuberance over the area of the implant, with an oval crater-like depression in the center. The periosteum did not cover the implant. The metal was markedly corroded and half absorbed. There was no evidence of infection.

Copper.—There seemed to be a marked bony proliferation. A moderate amount of scar tissue overlay the region of the implant. There was a bluish discoloration of the implant area for a distance of 2 cm. The region of the implant was the center of a large fusiform bony enlargement. The periosteum was continuous over the implant, which was bright and showed evidence of absorption. There was no evidence of infection.

Nickel.—There was a slight increase in the fibrous connective tissue overlying the implant, and a slight protuberance over the area of the implant with

an oval central depression. Dark discoloration extended for an area of 5 mm. about the implant. The periosteum was continuous over the implant, and the metal was discolored and corroded. There was no evidence of infection.

Aluminum Bronze.—There was a slight increase in fibrous connective tissue over the area of the implant. A dark discoloration extended over an area of 1 cm. The periosteum did not cover the implant, the area of which was noticeably depressed. There was no evidence of infection.

Magnesium.—There was a slight fusiform protuberance with a central depression over the area of the implant. The periosteum was continuous over the implant. The metal was three-fourths absorbed. There was a slight grayish discoloration about the implant for 0.5 cm. There was no marked productive change and no evidence of infection.

Aluminum.—There was a slight fusiform protuberance over the implant, and the periosteum was intact. The metal was not discolored or absorbed. There was a slight productive change with no evidence of infection.

Silver.—There was a slight increase of overlying fibrous connective tissue. The periosteum was intact. There was a slight protuberance. The metal was dark and slightly corroded, but the surrounding tissue was not discolored. There was slight productive change and no evidence of infection.

High Carbon Steel.—There was a slight depression over the area of implant. The periosteum was not intact over the implant. The area surrounding the metal was discolored for 1 cm. The metal was markedly discolored and corroded. There was moderate destructive change, but no infection.

Low Carbon Steel.—There was a slight increase in the overlying fibrous connective tissue, and a noticeable depression in the area of the implant. The periosteum was not intact over the implant. The tissue surrounding the metal was discolored for 1 cm., and the metal was markedly discolored and corroded. There was no evidence of infection, and only a slight destructive change.

Lead.—There was a slight increase in the overlying fibrous connective tissue, and a slight protuberance at the site of the implant, over which the periosteum was intact. There was no discoloration of the tissue although the metal was discolored. There was slight productive change.

Iron.—There was a slight increase of the overlying fibrous connective tissue, and a slight protuberance over the region of the implant, with a shallow central depression. The periosteum was intact, and there was no tissue discoloration although the metal was discolored. There was slight productive change.

Stellite.—There was a slight protuberance over the region of the implant. The periosteum was continuous over the implant, which was bright and not corroded. There was slight evidence of any reaction.

SERIES II. Ribs; four weeks.

Control.—There was a moderate fusiform enlargement at the site of the drill hole, and the periosteum was thickened.

Gold, Silver and Stellite.—There was a moderate fusiform swelling at the site of the implant. The metal was covered with thickened periosteum. There was no discoloration.

Zinc.—There was a large fusiform swelling, and the periosteum was much thickened over the region of the metal. There was slight discoloration, although the metal was partly absorbed and discolored. The swelling could be cut with a knife, and was friable on section. There was a definite fracture at the site of the implantation.

Copper.—There was a large fusiform swelling, and the region of the implant was overlaid with a moderately thickened periosteum. There was a 0.5 cm. zone of discoloration. The metal was bright and roughened.

Magnesium.—There was a large nodular swelling at the site of the implant. The metal was covered by thick periosteum, and was nearly absorbed. The discoloration was slight. The tissue was friable on section, and the periosteum was markedly thickened. There was a definite fracture at the point of injury.

Aluminum.—There was a moderate fusiform swelling at the site of the implant. The metal was bright, and there was no evidence of absorption. The periosteum was moderately thickened and covered the implant.

Lead.—There was a large fusiform swelling at the site of the implant. The periosteum was moderately thickened. The metal was corroded but covered, and

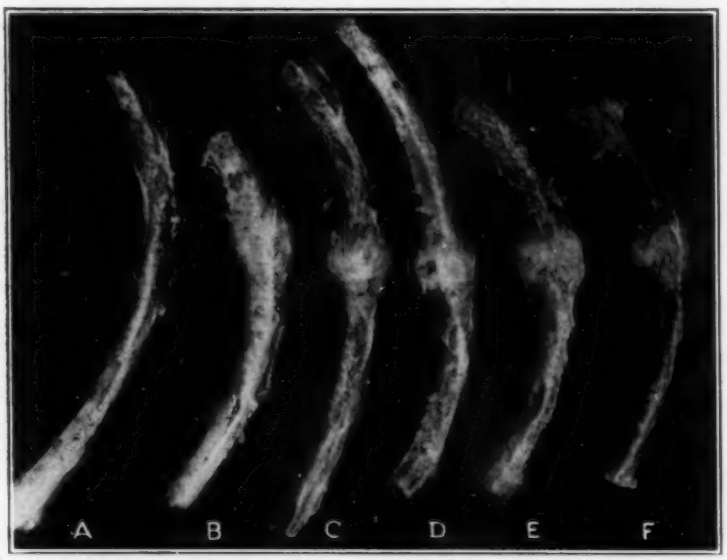

Fig. 1.—Gross specimens from Series II, showing the effect of fracture at the point of implantation; *a*, control; *b*, copper; *c*, lead; *d*, nickel; *e*, zinc; *f*, magnesium.

there was a slight discoloration. A fracture was present at the site of the implant.

Iron.—There was a moderate fusiform swelling at the site of the implant. The metal was discolored. The periosteum was moderately thickened, and slightly discolored about the implant.

High and Low Carbon Steel.—There was a moderate fusiform swelling at the site of the implant. The metal was not covered and was markedly corroded. There was a marked reaction of the surrounding connective tissue.

Nickel.—There was a moderate fusiform swelling at the site of the implant. The metal was not covered, and the surrounding periosteum was moderately thickened. The metal was corroded, and there was moderate discoloration of the tissue.

Aluminum Bronze.—There was a slight fusiform swelling with a central depression at the site of the implant. The metal was not covered. The periosteum was slightly thickened. The metal was bright, but the surface was roughened. There was slight discoloration.

SERIES III. Knee; two weeks.

Control.—There was a slight discoloration about the drill hole, and a thin layer of cartilage over the opening.

Gold and Aluminum.—There was a slight discoloration about the implant, which was covered with a thin layer of dense connective tissue.

Silver.—There was a moderate discoloration about the implant, which was covered with a thin layer of dense connective tissue.

Copper, Aluminum Bronze, Zinc and Magnesium.—There was very marked discoloration about the implant, the end of which was not covered.

Stellite.—There was a very slight discoloration about the implant, the end of which was covered with a thin layer of dense connective tissue.

Lead and Iron.—There was moderate discoloration about the implant, the end of which was not covered.

Nickel and High and Low Carbon Steel.—There was marked discoloration about the implant, the end of which was not covered.

SERIES IV. Skull; six weeks.

Control.—There was a slight increase in fibrous tissue. The margins of the trephine opening were slightly rounded and smooth. The periosteum was continuous over the bony defect, which was covered not by bone but by dense fibrous tissue. Bacteriologic cultures were negative.

Gold.—There was a slight fibrous tissue increase. The metal was covered by a dense fibrous tissue layer 1 mm. thick. The overlying periosteum was continuous. The metal was not corroded. There was a slight reaction.

Silver.—There was a slight fibrous tissue increase. The periosteum was continuous over the metal. The metal was covered by a 1 mm. layer of dense fibrous tissue, which contained no bony tissue. There was a zone of bluish discoloration over the metal and 2 or 3 mm. from the circumference. The metal was slightly corroded.

Zinc.—The metal was lying exposed under the superficial fascia. The periosteum was not continuous over the metal but only to the edge of the bony defect. There was a 0.5 cm. zone of marked connective tissue increase about the metal. The metal was badly corroded and slightly absorbed. The margins of the bony defect showed marked fibrous tissue increase.

Magnesium.—There was a moderate increase in the connective tissue over the metal and in a zone extending 1 cm. or more from the margins of the bony defect. The metal was overlaid by a dense fibrous tissue layer 2 or 3 mm. thick, containing no bony tissue. There was a notable protuberance of tissue over the metal. The metal was half absorbed.

Aluminum Bronze.—The metal was lying exposed under the superficial fascia. There was a moderate increase in the connective tissue. There was an area of dark discoloration for 1 cm. about the metal. The metal was very slightly discolored and the polish was dulled.

Copper.—The metal was lying exposed under the superficial fascia. The periosteum was not continuous. There was a zone of moderate connective tissue increase, and a zone of discoloration for 0.5 cm. The metal was bright, but showed signs of absorption.

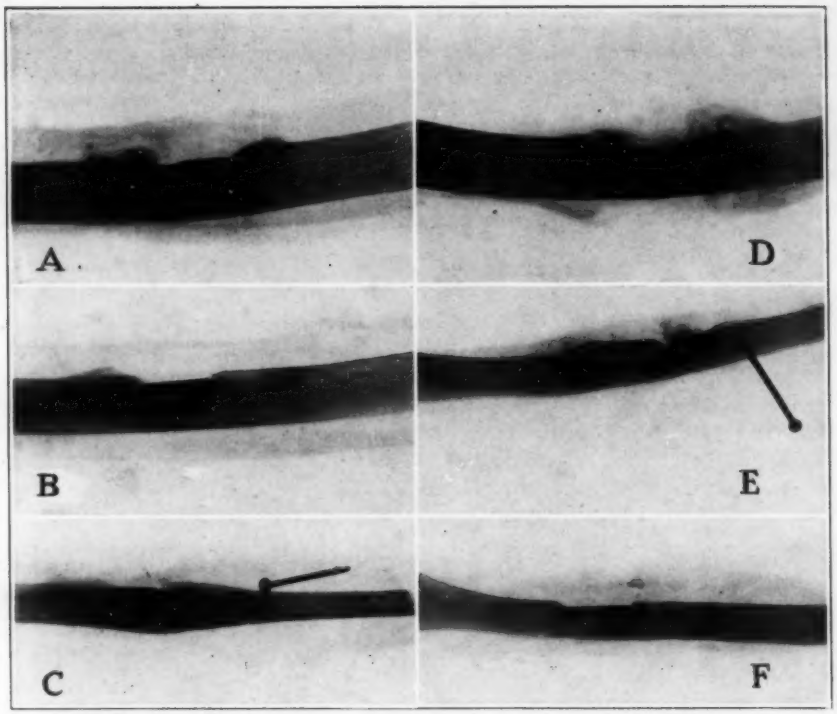

Fig. 2.—Appearance of rib after implantation of various metals; *A*, nickel; *B*, high carbon steel; *C*, zinc; *D*, magnesium; *E*, lead; *F*, low carbon steel.

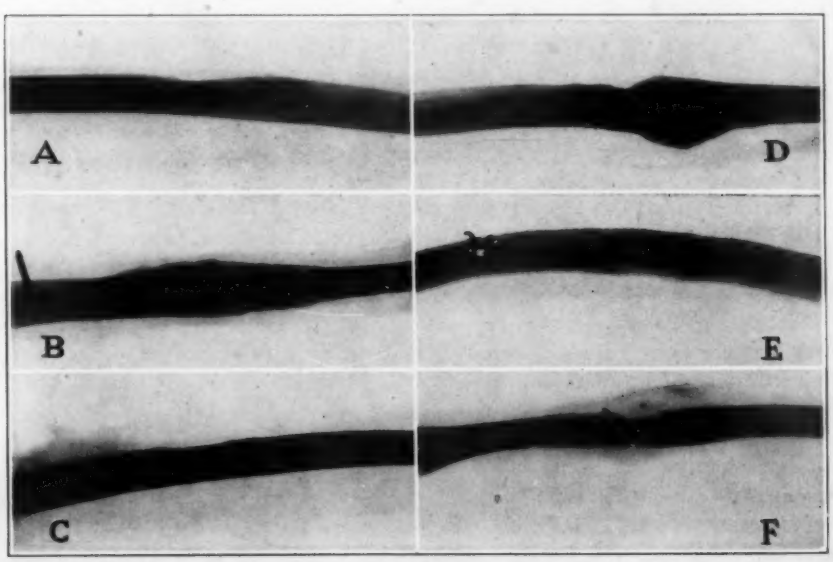

Fig. 3.—Appearance of tibia after implantation of various metals: *A*, control; *B*, copper; *C*, gold; *D*, aluminum; *E*, stellite; *F*, silver.

Nickel.—There was a slight increase in the connective tissue, and a zone of discoloration of 1 cm. There was a thin layer of fibrous tissue over the metal, which was discolored and corroded.

Aluminum.—There was a slight increase in the connective tissue. A bridge of bone 0.5 cm. wide and 1 mm. thick extended across the center of the metal, which was bright and not corroded. There was no discoloration.

Stellite.—There was a slight increase in the connective tissue. There was no discoloration. The metal was covered by a 1 mm. layer of very dense fibrous tissue, and was bright and not corroded. There was slight reaction.

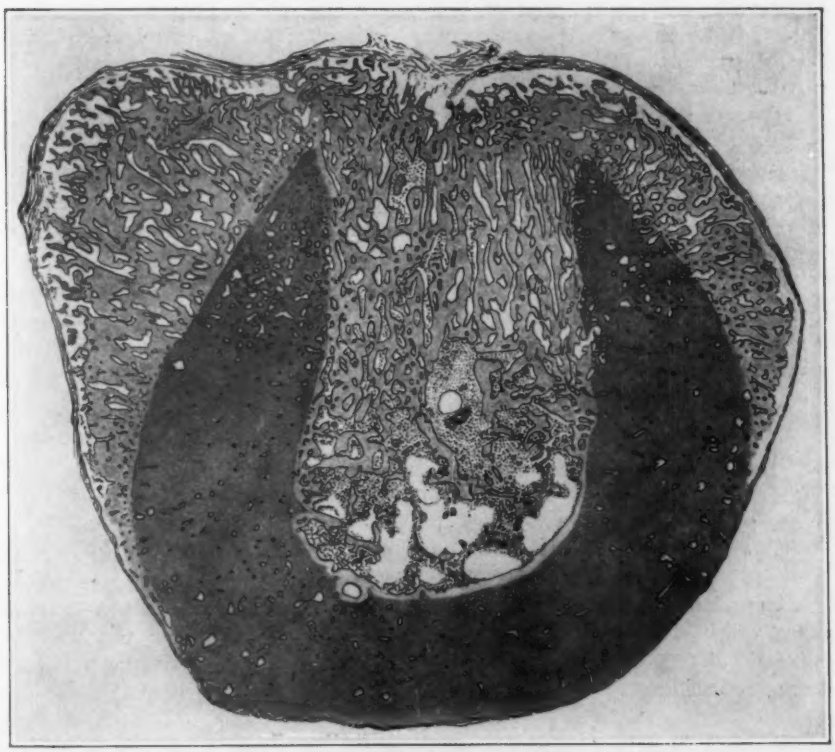

Fig. 4.—Cross-section of control tibia, showing the region of injury.

Lead.—There was a noticeable increase in the connective tissue. The metal was covered by a 2 mm. layer of dense fibrous tissue, and there was a zone of connective tissue proliferation for 0.5 cm. There was a slight surrounding discoloration, and the metal was discolored and corroded.

Iron.—There was a slight increase in the connective tissue. The zone of connective tissue increase was 0.5 cm., and there was a moderate discoloration for a distance of 0.5 cm. The metal was covered by a 1 mm. layer of dense fibrous tissue. The metal was slightly discolored.

High Carbon Steel.—The metal was lying exposed under the superficial fascia. There was moderate connective tissue increase for a zone of 0.5 cm.

and a moderate discoloration for a zone of 1 cm. The metal was discolored and corroded.

Low Carbon Steel.—The metal was only partially covered by a narrow thin zone of fibrous connective tissue. There was moderate discoloration for a distance of 2 cm., and the metal was discolored and corroded.

SERIES V. Ribs; four weeks.

Control.—A roentgen ray of the injured portion of the rib showed that the defect was nearly filled with bone of normal density. There was a slight shallow depression at this point, and no callous formation.

Aluminum.—About the region of the implant was a moderate fusiform bony overgrowth, which was more marked on the side opposite the point of injury. Directly through the area was a thin line of rarefaction, which might be indicative of fracture. The metal was well encapsulated in bone of normal density and there was no discernible callous formation.

High Carbon Steel.—The bone of the specimen appeared rarefied throughout its length and particularly in the neighborhood of the distal end of the metal. There was a very small amount of callus a short distance from the proximal end, but this was barely noticeable. There was no attempt at bony encapsulation of the metal and only a very slight bone regeneration at either end of the implant.

Zinc.—About the region of the implant was a slight fusiform thickening, more noticeable on the side opposite the injury where it appeared as subperiosteal. About the ends of the metal, there was a small amount of callus, which was partly calcified. The metal was not encapsulated by bone, but near the ends there was some evidence of regeneration.

Silver.—In the region of the implant, there was a fusiform mass of callus which was somewhat excessive. Opposite the point of injury, there was a moderately thick layer of subperiosteal bone. The metal was covered by bone in its distal half, but in the proximal portion this was deficient, probably because the implant was bent so that the tip pointed outward. There was considerable bone regeneration and a definite tendency to encapsulation.

Magnesium.—About the region of the implant was a large fusiform mass of callus which showed but little evidence of calcification. There was no bone filling the defect, and the metal was entirely absorbed. The rib was relatively dense in structure, but apparently actual bone growth was negligible.

Copper.—The region of the implant showed a moderate fusiform enlargement, which consisted chiefly of new subperiosteal bone, which was as dense as the normal structure. The metal was well imbedded and was completely encapsulated in new dense bone.

Low Carbon Steel.—Over the rib defect was a slight amount of callus showing no evidence of calcification. There was no bone overlying the metal, and apparently there was no attempt at new bone formation. The rib appeared slightly rarefied toward its proximal end.

Nickel.—At either end of the metal were small callus masses which appeared to be undergoing calcification. On the opposite side of the rib was a fusiform mass of callus not calcified. The metal was not covered by bone, but at the extreme ends there appeared slight evidence of bone growth.

Lead.—Over the region of the implant was a moderately thick fusiform mass of callus, which was slightly calcified near the metal ends. One end of the

metal was displaced outward and held in what appeared as new bone growth. There was slight bone regeneration and no tendency to bony encapsulation.

Stellite.—The bony contour was normal, and there was no callus or bone overgrowth. The metal was deeply imbedded and covered with new bone, slightly less dense than normal.

Gold.—There was a very slight shallow depression at the site of the implant, and a large mass of callus near one end. The callus was not calcified. The metal was covered with a thin layer of bone of normal density. The whole bone and particularly that portion underlying the implant appeared denser than normal.

Iron.—There was a shallow depression at the site of the implant, and on the opposite side of the bone a narrow fusiform mass of uncalcified callus. There was a small mass of new bone at either end of the metal, but there was no tendency to encapsulation.

Aluminum Bronze.—There was a moderate fusiform mass of uncalcified callus about the region of the implant. At either end of the metal, there was a moderate sized hump of subperiosteal bone nearly as dense as normal. No bone covered the greater part of the metal, and there was no bony encapsulation.

MICROSCOPIC FINDINGS

SERIES 1. Tibia; six weeks.

Silver.—The implant was surrounded by a closely applied narrow zone of dense fibrous tissue.

Medulla: The quadrant opposite the implant was filled with thick trabeculae of new bone and large sinuses engorged with red blood cells. The interstices were filled with a few shrunken and small fat cells, supported by a fine reticulum of connective tissue cells. The marrow cells were chiefly of connective tissue and endothelial types. The rest of the medulla and cortical defect was filled with new bone interspersed with large irregular haversian spaces and well filled blood sinuses. The cortical bone was normal except opposite the internal end of the implant and at the margin of the cortical defect, where many enlarged haversian canals were found lined with osteoblasts.

Periosteum: The quadrant of the region of the cortical defect overlay a thick crescent of new subperiosteal bone, continuous over the implant. A thin layer of subperiosteal bone completely surrounded the section. The periosteum was thick and lined with osteoblasts.

Zinc.—The implant was surrounded by a thin layer of dense fibrous connective tissue which was closely approximated by new bone.

Medulla: The medullary cavity contained a few thin trabeculae of new bone, which were more numerous in the region of the implant. Interspersed were a few fat cells and adult connective tissue cells and masses of marrow cells of leukocytic and endothelial types.

Cortex: The region of the cortex was composed of new bone with relatively small haversian spaces filled with a reticulum of connective tissue and osteoblasts. There were numerous blood sinuses. The cortex elsewhere was normal.

Periosteum: The periosteum was slightly thickened over the region of the implant and dipped down to meet the outer end of the implant. There was a moderately thick mass of subperiosteal bone on either side of the implant but not covering it.

Copper.—The implant was surrounded by a thin, closely applied zone of fibrous connective tissue, which in turn was completely surrounded by rather dense new bone.

Medulla: The medullary portion was almost completely filled with moderately dense new bone interspersed with a few fat cells and masses of marrow cells

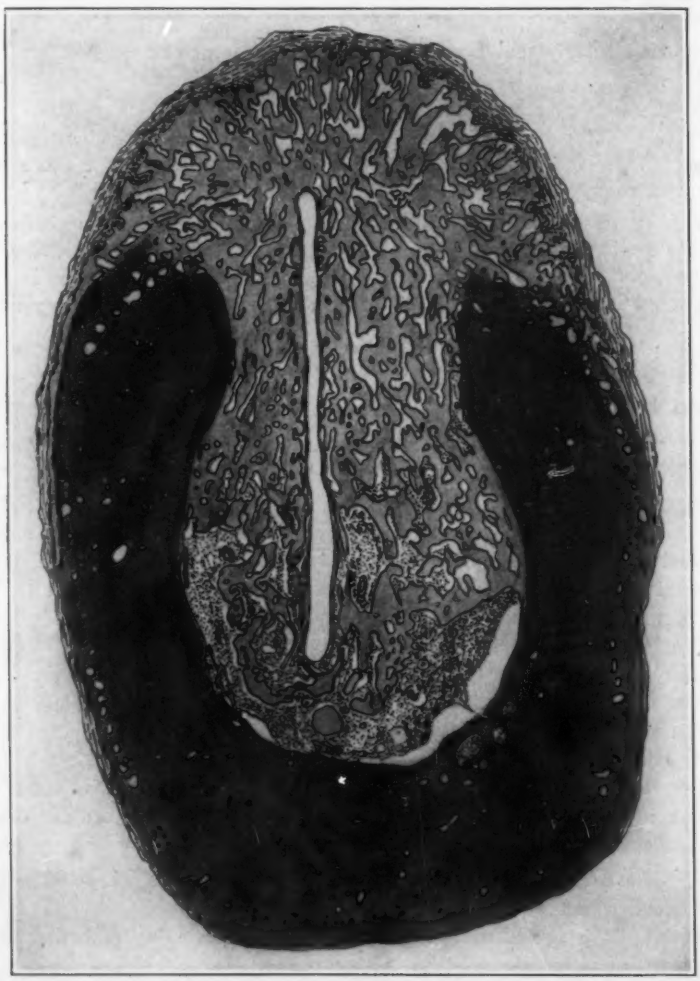

Fig. 5.—Cross-section of tibia, showing the region of gold implant (slightly reduced from drawing × 10.5).

chiefly of the endothelial type, and connective tissue cells to form a network of collagen fibrils. The whole medullary cavity was more completely filled than in other sections.

Cortex: The region of the cortical defect was filled with new bone of the same character as that in the medulla, and completely covered the outer end

of the implant. The remainder of the cortex was normal except for a general increase in the size of the haversian canals, which contained many osteoblasts and a few giant cells.

Periosteum: The periosteum over the half containing the implant was moderately thickened and underlying it was a very thick crescent of new subperiosteal bone which almost completely surrounded the cortex. In the outer portion of this crescent were several areas made up of dense masses of cartilage. The periosteum dipped down in the region of the cortical defect to form a wedge of fibrous connective tissue.

Magnesium.—The implant was surrounded by a thick layer of fibrous connective tissue interspersed with marrow cells of the endothelial type.

Medulla: The medulla was made up of dense masses of marrow cells, chiefly of the endothelial type, interspersed with a moderate number of fat cells. New bone was present in thin anastomotic trabeculae and relatively small in amount.

Cortex: The region of the cortical defect was filled with thick, short anastomotic trabeculae of new bone, forming large haversian spaces filled with connective tissue cells and a fine collagen reticulum, and lined with osteoblasts. The new bone did not closely approximate the implant nor did it cover the outer end. The remainder of the cortex was normal.

Periosteum: The quadrant overlying the implant was moderately thickened, the remainder being normal. There was a thick wedge shaped area of new subperiosteal bone on either side of the outer end of the implant.

Aluminum.—The implant was surrounded by a thin layer of fibrous connective tissue which contained a few large cells of the endothelial type.

Medulla: The medullary cavity was filled for the greater part with large clear fat cells and masses of marrow cells, chiefly of the endothelial type. There was a loose reticulum of connective tissue cells with fine collagen fibrils. New bone was present in the form of thin anastomotic trabeculae which were more densely arranged as the cortical defect was approached.

Cortex: The cortical defect was filled with new bone having moderately large haversian spaces filled with osteoblasts and a connective tissue reticulum. The outer end of the implant was not covered by new bone but was closely approximated. The remainder of the cortex was normal.

Periosteum: The periosteum was slightly thickened in the quadrant overlying the implant, which it covered. Underlying this were two thin crescents of new subperiosteal bone. Elsewhere the periosteum was normal.

Nickel.—The implant was surrounded by a wide zone of densely arranged marrow cells chiefly of the granular leukocytic type interspersed with a few bands of fibrous connective tissue. Toward the medullary end were a few fat cells.

Medulla: The medulla was filled with several large masses of new bone with small haversian spaces. The spaces were filled with a reticular connective tissue, and large marrow cells of the granular leukocytic type. Osteoblasts were numerous and there were occasional giant cells. The interstices between the masses of new bone contained a fine reticular connective tissue network holding marrow cells of various types and many shrunken opaque fat cells.

Cortex: The region of the cortical defect was filled with rather dense new bone with small haversian spaces in which were intermingled marrow cells of the endothelial type and connective tissue cells with long collagen fibrils, also the

usual osteoblasts. The new bone did not closely approximate the implant, nor did it cover the outer end, but rounded off, leaving a wedge shaped defect filled with connective tissue cells and marrow cells. The remainder of the cortex was normal.

Periosteum: The periosteum of the quadrant overlying the implant was markedly thickened and underlaid on each side of the implant by a half crescent of new subperiosteal bone. The remainder was normal.

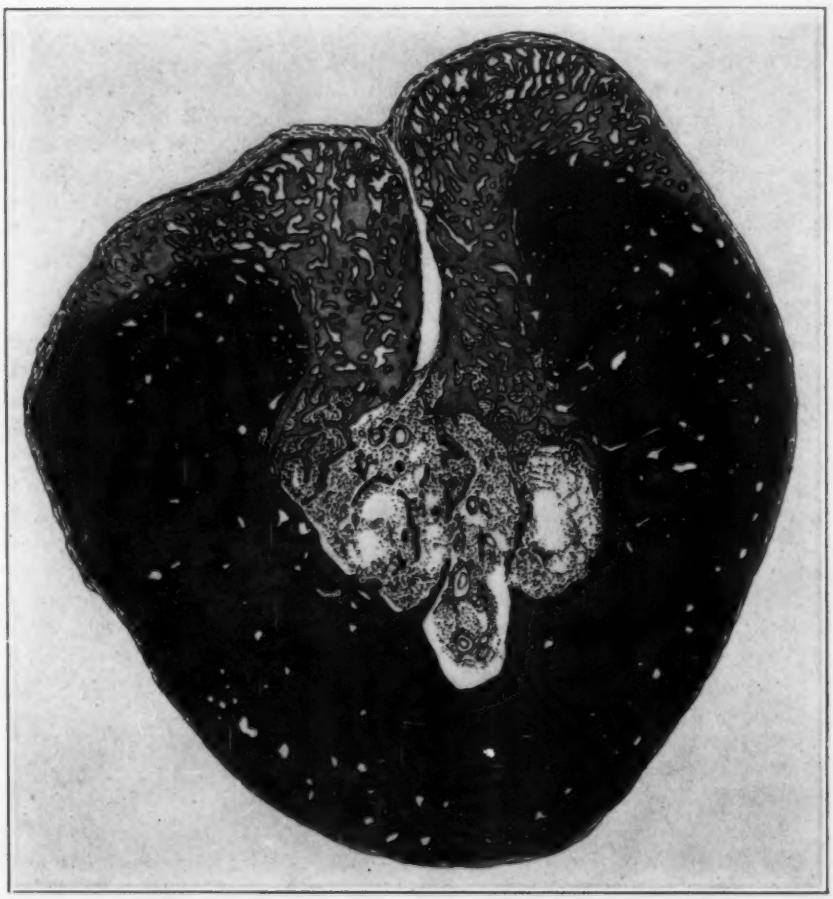

Fig. 6.—Cross-section of tibia, showing region of zinc implant.

Stellite.—The implant was surrounded by a closely applied thin layer of fibrous connective tissue. In many places, this layer was absent and the endosteum of the new bone approximated the metal.

Medulla: The medullary space was filled for the most part with widely separated budlike processes of new bone. In the neighborhood of the implant, these were anastomotic. The interstices were filled with a few large clear fat cells, but chiefly with dense masses of large marrow cells of the endothelial type.

Cortex: The region of the cortical defect was filled with a rather dense network of new bone. The interstitial spaces were filled with osteoblasts and

a fine reticulum of connective tissue. Sinuses were few and well filled. The new bone was especially dense and closely applied to the outer half of the implant. The remaining cortex was normal.

Periosteum: The periosteum was normal except for a slight thickening in the quadrant overlying the implant. There was a moderately thick crescentic area of new subperiosteal bone in this region.

Lead.—The implant was surrounded by a closely applied thick layer of fibrous connective tissue interspersed with leukocytic marrow cells.

Medulla: The medullary cavity was filled with short thick budding trabeculae of new bone interspersed with large well filled blood sinuses and marrow cells chiefly of the connective tissue type. There were a few normal fat cells.

Fig. 7.—Cross-section of tibia, showing region of copper implant.

Cortex: The region of the cortical defect was filled with long anastomotic trabeculae of new bone running for the most part parallel with the metal and not completely covering the extreme end. The interstices were filled with marrow cells of the endothelial type and blood sinuses. The cortex was otherwise normal. The endosteum was thick and proliferating.

Periosteum: The periosteum over the implant was only slightly thickened, and there was a narrow crescentic zone of new subperiosteal bone. The remaining portion of the periosteum was normal.

Iron.—The implant was surrounded by a moderately thick zone of fibrous connective tissue. At a few points close to the metal were giant cells reacting to a specific stain for hemosiderin. These were very few in number as compared to the high carbon steel sections and were not found in the surrounding tissues.

Medulla: The greater portion of the medullary cavity was filled with widely spaced thin trabeculae of new bone, the interstitial spaces being filled with small normal fat cells and densely packed marrow cells of the leukocytic type. Blood sinuses were not numerous or large. The endosteum was thin and inactive.

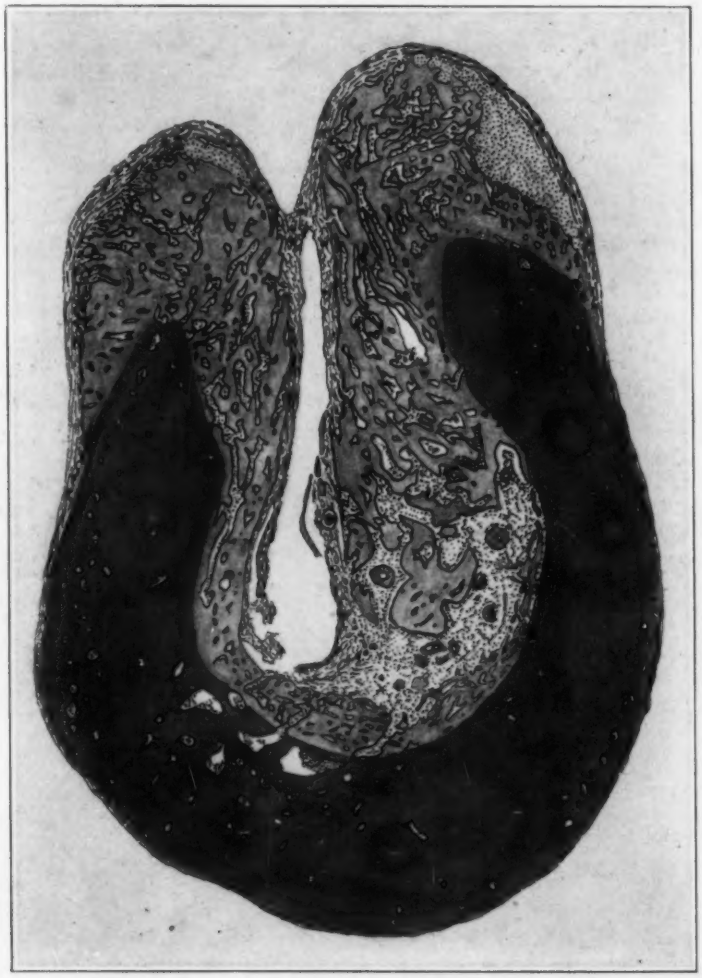

Fig. 8.—Cross-section of tibia, showing region of nickel implant (slightly reduced from drawing × 10.5).

Cortex: The cortical defect was filled about the implant with rather dense new bone with small haversian spaces. The new bone closely approximated the metal at several points, but did not cover the external end, where it divided into two wedge shaped masses. The cortex was otherwise normal.

Periosteum: The periosteum did not cover the implant but was slightly thickened in that region. The remaining portion was only slightly thicker than

normal. On either side of the implant were two moderately thick wedges of subperiosteal bone.

Gold.—The implant was completely surrounded by new bone, which was separated from it by a very thin layer of fibrous connective tissue.

Medulla: The greater portion was filled with thick buds and trabeculae of new bone. The region about the internal end of the implant contained

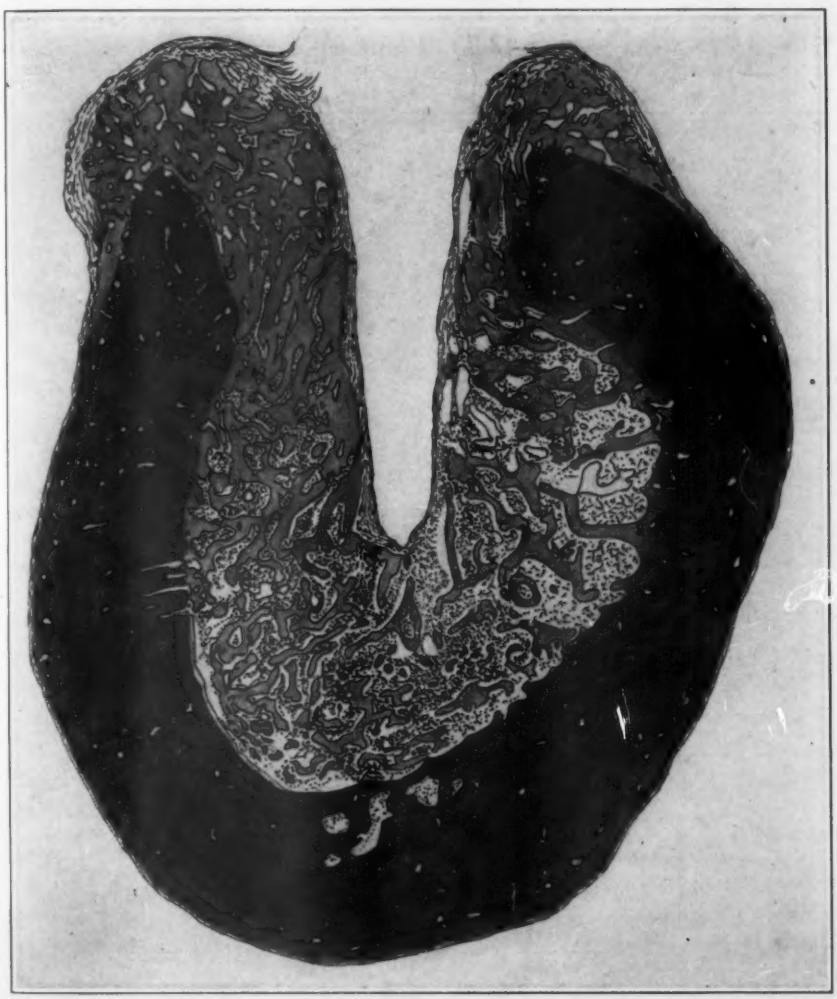

Fig. 9.—Cross-section of tibia, showing region of copper-aluminum alloy implant.

numerous larger spaces filled with shrunken fat cells, marrow cells of the connective tissue type and well filled blood sinuses. The endosteum throughout was thickened and, as the region of the cortical defect was approached, the new bone became denser and the haversian spaces smaller. There was a marked overgrowth of new bone over the external end of the implant.

Cortex: The cortical bone was normal except for a few enlarged haversian canals. In the region of the defect, most of these were filled with osteoblasts, but a few contained fat cells.

Periosteum: Over the cortical defect was a large crescentic area of new bone over which the periosteum was markedly thickened and active. The remaining periosteum was only slightly thickened.

Aluminum Bronze.—The implant was surrounded, except for the extreme end, by a thick, dense zone of connective tissue.

Medulla: The medulla was filled with anastomotic trabeculae of new bone interspersed with large dense masses of marrow cells, chiefly of the endothelial

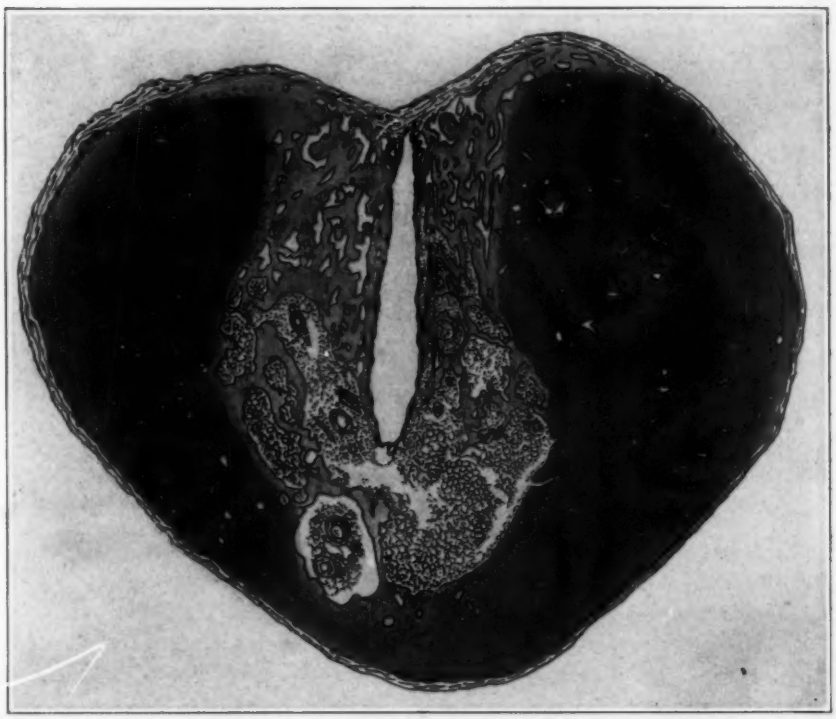

Fig. 10.—Cross-section of tibia, showing region of aluminum implant (slightly reduced from drawing × 10.5).

type, and areas of normal fat cells. There were some areas of shrunken and opaque fat cells.

Cortex: The cortical defect was filled with new bone, interspersed with long narrow haversian spaces which were lined with osteoblasts and numerous well filled blood sinuses. The cortical bone was normal except for a few enlarged haversian canals in the region of the defect, filled with osteoblasts. As the periosteum was approached, the new bone receded from the implant, forming an open V.

Periosteum: The quadrant over the implant was markedly thickened, and the outer end of the implant was not covered. At each border of the cortical

defect was a wedge shaped area of new periosteal bone. The periosteum about the remaining portion of the bone was slightly thickened.

Control.—Medulla: The half opposite the cortical defect was filled with thin anastomotic trabeculae of new bone, interspersed with marrow cells of the endothelial type and groups of large clear fat cells. The endosteum was thick and covered a thin layer of subendosteal bone. The cortical defect was filled with new bone trabeculae, which was continuous with a crescentic area of subperiosteal bone over the region of the defect.

Cortex: There was a slight increase in the number of large haversian canals. On the borders of the defect and in the cortical bone directly opposite were numerous enlarged haversian spaces lined with osteoblasts.

Periosteum: This was normal except for the third overlying the region of the defect, where it was much thickened.

High Carbon Steel.—The implant was surrounded by a moderately thick zone of cellular connective tissue intermingled with large pigmented cells which reacted strongly to a specific stain for hemosiderin.

Medulla: The medullary portion contained a few small buds of new bone, but for the most part was made up of fat cells and marrow cells of the leukocytic and endothelial types. Many of the fat cells were shrunken and opaque.

Cortex: The region of the cortex was only partly filled with new bone, made up of rather thin anastomatic trabeculae and large interstitial spaces filled with a reticulum of connective tissue and marrow cells. On the whole, the new bone was very small in amount and in no place did it approximate the implant. At the outer end, it thinned out and sloped away from the implant. The cortex elsewhere was normal.

Periosteum: The periosteum, while slightly thickened in the region overlying the implant, did not cover it but dipped down on either side. There was a narrow half crescent of new subperiosteal bone on either side of the implant.

Low Carbon Steel.—The implant was surrounded by a thick zone of fibrous connective tissue interspersed with marrow cells, chiefly of the endothelial types. Throughout this zone were numbers of large pigmented cells, which reacted to a specific stain for hemosiderin.

Medulla: The greater part was made up of masses of marrow cells, mostly of the endothelial type, interspersed with fat cells. Many fat cells were shrunken and opaque. There were a few thin trabeculae of new bone, which were most numerous as the cortical defect was approached.

Cortex: The cortex was normal except for the region of the defect, which was filled with anastomotic trabeculae of new bone. The amount of bone was relatively small and did not approach the implant closely. The cortex had several large haversian spaces opposite the point of implantation. They contained some fat cells, together with connective tissue cells and a few osteoblasts.

Periosteum: This was slightly thickened over the quadrant of the implant, but was not continuous across it. There were two narrow segments of new subperiosteal bone on either side of the implant, but not continuous over the outer end of the implant. The remainder of the periosteum was normal.

SERIES III. Femur.

High Carbon Steel.—Zone 1: The implant was surrounded by a relatively wide zone of densely massed, large, clear, polygonal cells with eccentric vesicular nuclei. Interspersed were many concentrically arranged fusiform cells with oval nuclei. Also in this area were a number of large giant cells which appeared brown

to hematoxylin and eosin, and reacted to a special stain for hemosiderin. This type of cell was found scattered for some considerable distance from the implant. Bone trabeculae were somewhat thickened, but few and scattering. The lamellar structure was well defined, and there was little evidence of new

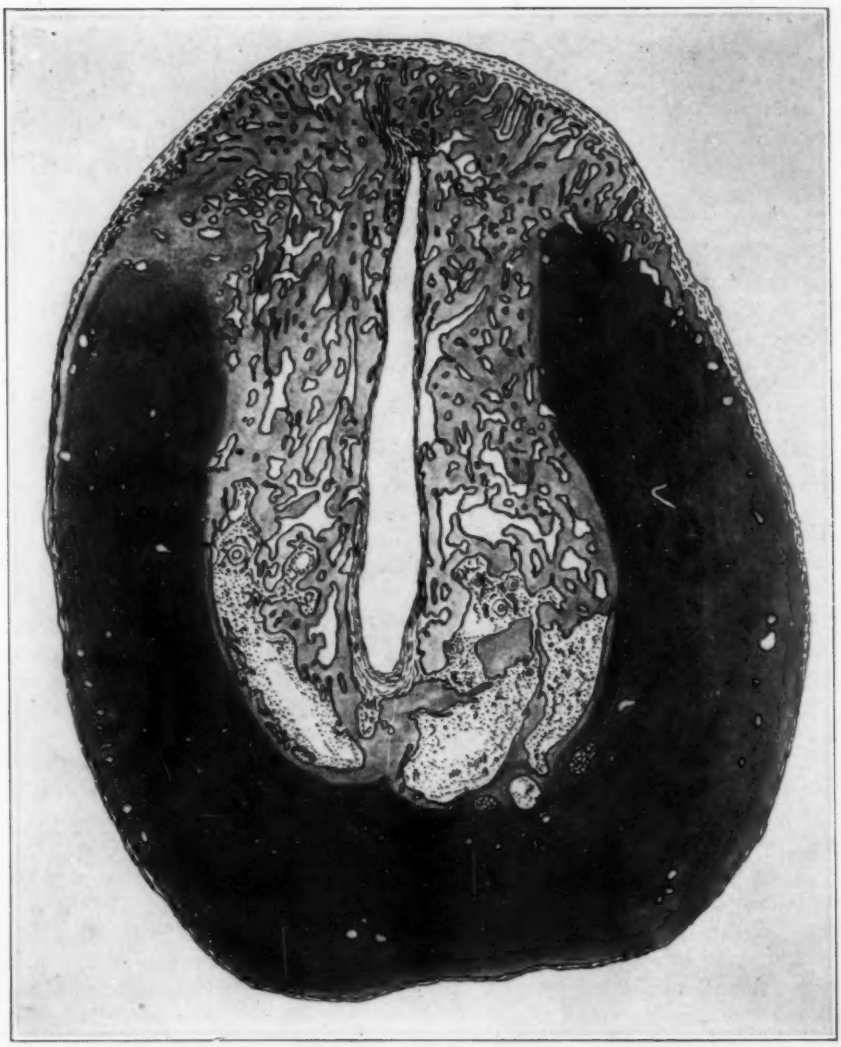

Fig. 11.—Cross-section of tibia, showing region of silver implant (slightly reduced from drawing × 10.5).

bone formation. The endosteum, while slightly thickened in a few places, was, for the most part, normal. There were no fat cells in this region.

Zone 2: The trabeculae were normal. The interstices were filled with large clear or finely granular cells, with rounded, vesicular nuclei. The fat cells were fewer and smaller than normal.

Zone 3: This region was normal except for a decrease in the number and size of the fat cells, and a slight predominance of the large clear cells, noted in Zone 2.

Magnesium.—Zone 1: The implant was surrounded by a thick layer of concentrically arranged fusiform cells with oval nuclei. Interspersed were numbers of large polygonal cells with finely granular cytoplasm and round dense nuclei. The trabeculae were thick, numerous and anastomotic. There were many budding

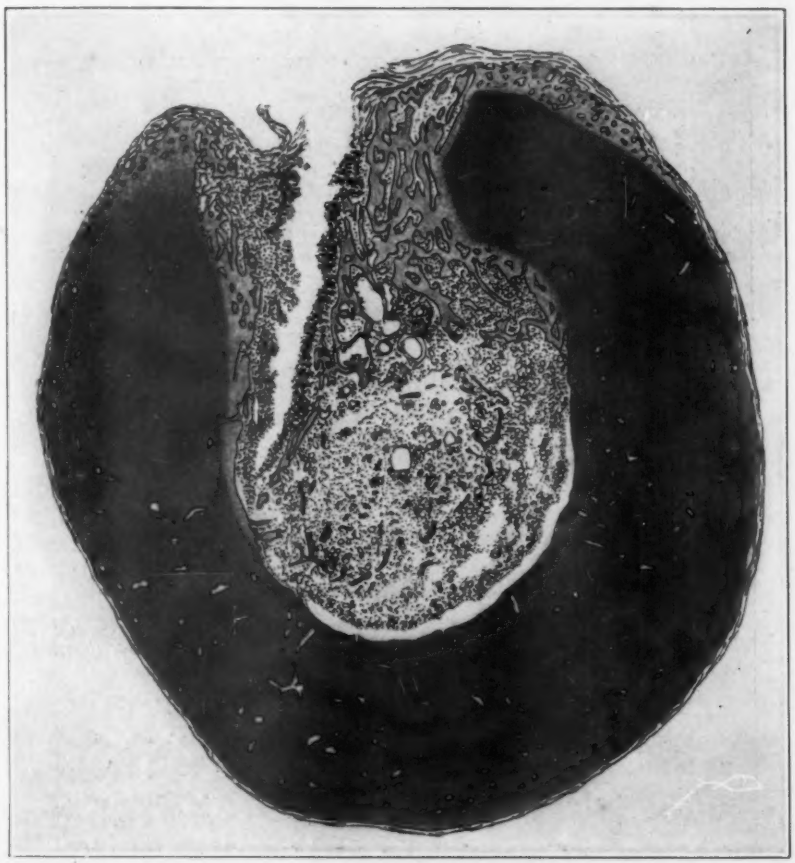

Fig. 12.—Cross-section of tibia, showing region of high carbon steel implant.

projections of new bone. The endosteum was thick and made up of two or three layers of cells. There were no fat cells present in this region.

Zone 2:—The trabeculae were relatively thick and anastomotic. The included bone cells were large and oval. The laminated structure was not well defined. There were no budding projections of new bone, but the endosteum was thick, and in places made up of two or three layers of cells. The interstitial marrow cells were in dense masses, the predominating type being large and polygonal, and having a finely granular cytoplasm and a dense round nucleus. The fat cells were few in number and smaller than normal.

Zone 3: This region approximated the normal except for slightly thicker bone trabeculae and smaller interstitial spaces. At one point, there appeared an irregular ring of cartilage.

Zinc.—Zone 1: The implant was surrounded by a closely applied dense zone consisting of several concentric layers of spindle shaped cells with elongated dense nuclei. This zone contained a number of sinuses well filled with red blood cells. The trabeculae were thick, short and anastomotic. New layers of bone were well differentiated. Many large included bone cells were present and many budding projections of growing bone.

Fig. 13.—Cross-section of tibia, showing region of low carbon steel implant.

The endosteum was a thick single layer of oval cells with oval vesicular nuclei. There were many osteoblasts and numerous giant cells. The sinuses were markedly engorged with red blood cells. The few fat cells were shrunken, deformed and cloudy. The interstitial cells consisted of many oval and spindle shaped cells with clear cytoplasm and oval vesicular nuclei. There were many rounded and polygonal cells with finely granular cytoplasm and round relatively dense nuclei. There were many similar cells with polymorphonuclear forms, and a few large oval and irregular cells with coarsely granular cytoplasm and eccentric, round nuclei. A few red blood cells were present.

Zone 2: The trabeculae were slightly thickened and anastomotic and the laminated structure was well defined. There were many included elongated bone cells. The endosteum consisted of a thick single layer of spindle shaped cells with relatively dense, oval nuclei. There were a few osteoblasts and an occasional giant cell. The sinuses were few, and were well filled with red blood cells.

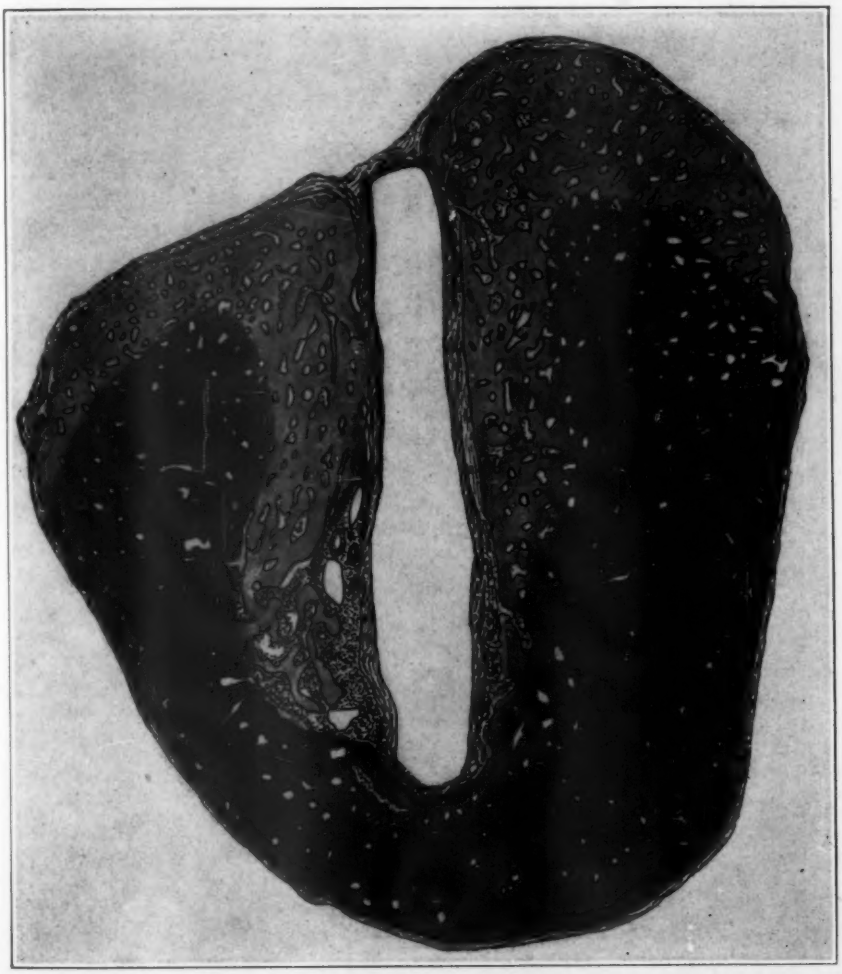

Fig. 14.—Cross-section of tibia, showing region of iron implant.

The fat cells were few in number, small, clear and distended. Of the interstitial cells, the predominating types were large irregular cells, with clear cytoplasm and large oval vesicular nuclei. Many polygonal and rounded cells with finely granular cytoplasm and round relatively dense nuclei were seen. A few red blood cells and a few large irregular cells with coarsely granular cytoplasm and round relatively dense nuclei were present.

Zone 3: This was normal except for the interstitial cells, of which those predominating were large irregular cells with clear cytoplasm and oval vesicular nuclei.

Nickel.—Zone 1: There was a dense cellular exudate about the implant, consisting of many polymorphonuclear leukocytes. Many large irregular cells with eccentric, round, relatively dense nuclei and finely granular cytoplasm were

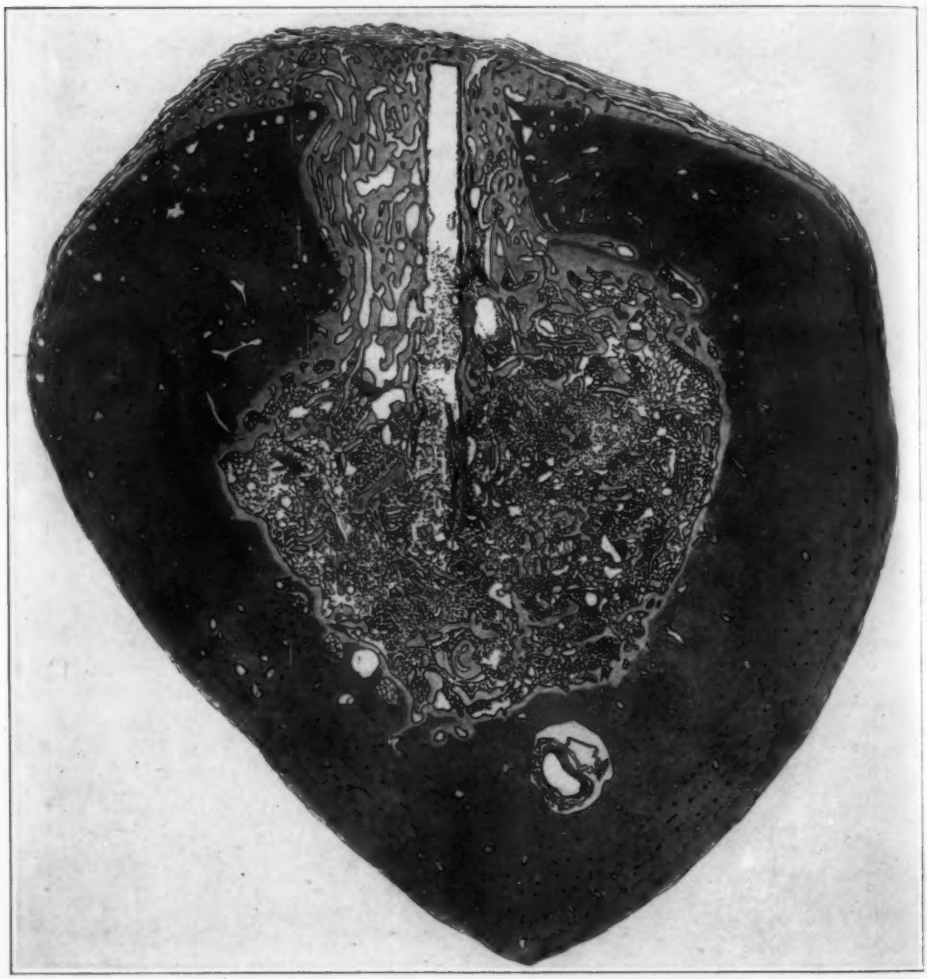

Fig. 15.—Cross-section of tibia, showing region of stellite implant.

distinguished, together with numerous large polygonal cells of a clear cytoplasm and oval, vesicular nuclei. There were numerous red blood cells. Next to these was a dense zone of elongated cells with clear cytoplasm and oval vesicular nuclei. Adjoining this were occasional buds of growing bone.

The trabeculae were widely separated, thin and short, with their laminated structure well defined. There were numerous oval, isolated bone cells in the new bone and many osteoblasts bordering the budding new bone growth.

The endosteum consisted of single and double layers of large cells with large oval nuclei. Fat cells were not present.

The predominating type of the interstitial cells was large and fusiform, with an oval vesicular nucleus. There were many large polygonal cells with clear cytoplasm and round vesicular nuclei, and a number of large, irregular cells with finely granular cytoplasm and eccentric relatively dense nuclei. A few red blood cells were to be seen, and the sinuses were engorged.

Zone 2: The trabeculae were thin, widely separated and anastomotic, with a definite laminated structure. There were a few budding projections of growing bone, and isolated bone cells in the usual number, small and oval. Osteoblasts were few. The endosteum consisted of a thin, single layer of cells with small elongated dense nuclei. The fat cells were few in number, small, round and clear. The sinuses were engorged.

The predominating type of the interstitial cells was the large polygonal cells, with clear or finely granular cytoplasm and large, round or oval, vesicular nuclei. There were many polymorphonuclear forms and a few red blood cells.

Zone 3: This zone was similar to Zone 2, except that there were more and larger fat cells and fewer polymorphonuclear forms.

Aluminum.—Zone 1: The implant was surrounded by a closely applied dense zone of spindle shaped connective tissue cells arranged in three or four layers. But for the new bone, the connective tissue layer came very close to the implant.

The trabeculae were somewhat thickened, short and anastomotic. Many budding projections of new bone were seen and the lamellar structure was not well defined. There were many large, isolated oval bone cells. Osteoblasts were numerous, as were also giant cells.

The endosteum consisted for the most part of a thin, single layer of cells with elongated, dense nuclei. In places, larger cells were present, but in a single layer. The sinuses were moderately filled. The fat cells were few in number and small, clear and distended.

The predominating type of interstitial cell was moderate sized, polygonal, with a round vesicular nucleus and a relatively clear cytoplasm. There were a few polymorphonuclear leukocytes and transitional types and a few large irregular cells with coarse granules together with a few red blood cells.

Zone 2: The trabeculae and fat cells were slightly smaller than normal. The endosteum was normal, as were the sinuses.

Of the interstitial cells, which occurred in slightly greater masses than normal, about half were moderately sized and polygonal with clear cytoplasm and round vesicular nuclei. Some had a finely granular cytoplasm and relatively dense nuclei. There were a few red blood cells and a few large cells with coarse granules.

Zone 3: This was normal.

Lead.—Zone 1: The implant was surrounded by a closely applied dense zone of several layers of concentrically arranged spindle cells. In a zone between this and the surrounding bony trabeculae were many small sinuses engorged with red blood cells.

The trabeculae were thick and widely separated, and there were many budding projections of growing bone in which the laminated structure was well defined. Many oval included bone cells were to be seen.

The endosteum consisted for the most part of a thin single layer of spindle cells with elongated dense nuclei; although many areas of single and double layers of oval cells with oval, relatively dense nuclei were to be noted. There

Fig. 16.—Gold disk in trephine opening in skull.

Fig. 17.—Silver disk in trephine opening in skull.

Fig. 18.—Aluminum disk in trephine opening in skull.

Fig. 19.—Steel disk in trephine opening in skull.

were numerous osteoblasts in the growing areas, and occasionally giant cells. The sinuses were numerous and engorged with red blood cells. The fat cells were shrunken, distorted and slightly opaque.

The predominating type of interstitial cell was rounded and had a finely granular cytoplasm and a relatively dense round or polymorphic nucleus. There were many large cells with clear cytoplasm and oval vesicular nuclei and many spindle cells.

Zone 2: The bony trabeculae and endosteum were normal. The sinuses were many, and were engorged with red blood cells. The fat cells were normal in number but were slightly smaller than normal, round, clear and distended.

Zone 3: This was normal.

Aluminum Bronze.—Zone 1: The implant was surrounded by a closely applied dense zone of cells, of which the predominating type was oval or fusiform with a clear cytoplasm and oval vesicular nucleus. There were many rounded polygonal cells with finely granular cytoplasm and round, relatively dense nuclei, and a number of red blood cells. Surrounding this zone was a zone of short, thick bony trabeculae, with few anastomoses. The laminated structure was not defined. There were many large polygonal included bone cells. Some trabeculae had endosteum consisting of a thick layer of large, oval or spindle cells, with large oval vesicular nuclei.

The sinuses were numerous and engorged. There were no fat cells present.

The predominating type of interstitial cell was oval or spindle shaped with clear cytoplasm and a large oval vesicular nucleus. There were a few rounded cells, with finely granular cytoplasm and round, relatively dense nuclei.

Zone 2: The bone trabeculae were thin and widely separated. The laminated structure was well defined. The included bone cells were oval and small.

The endosteum consisted of a thin, single layer of spindle cells. A few osteoblasts could be noted on the ends of the trabeculae, also occasional giant cells.

The fat cells were relatively few in number. Some were large, clear and distended, and some small, clear and distended. Some were small, shrunken, deformed and slightly opaque.

The interstitial cells were chiefly rounded cells, with finely granular cytoplasm and round, relatively dense nuclei. There were a number of large rounded cells with coarse, granular and round, exceedingly dense nuclei, and a number of polygonal cells with clear cytoplasm and oval vesicular nuclei.

The sinuses were moderately engorged with red blood cells.

Zone 3: This was normal except that the fat cells were fewer and smaller and of interstitial cells there were more polygonal, with clear cytoplasm and oval vesicular nuclei.

Iron.—Zone 1: The implant was surrounded by a narrow zone of closely packed cells. The predominating type was large and polygonal, with finely granular cytoplasm and a round relatively dense eccentric nucleus. There were many smaller, round cells, with finely granular cytoplasm and polymorphonuclear and transitional types of nucleus. Many were oval and elongated cells, with clear cytoplasm and oval vesicular nuclei. There were a few giant cells, and numerous red blood cells.

The trabeculae were anastomotic and thickened, and the laminated structure was defined except where new bone was laid down. Many budding projections of new bone and many included oval bone cells were to be seen.

The endosteum consisted for the most part of thin and single layers of cells with oval nuclei. About the new bone areas, the cells were larger and more

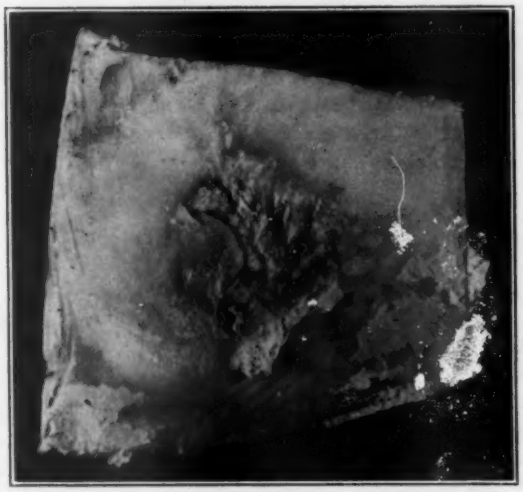

Fig. 20.—Stellite disk in trephine opening in skull.

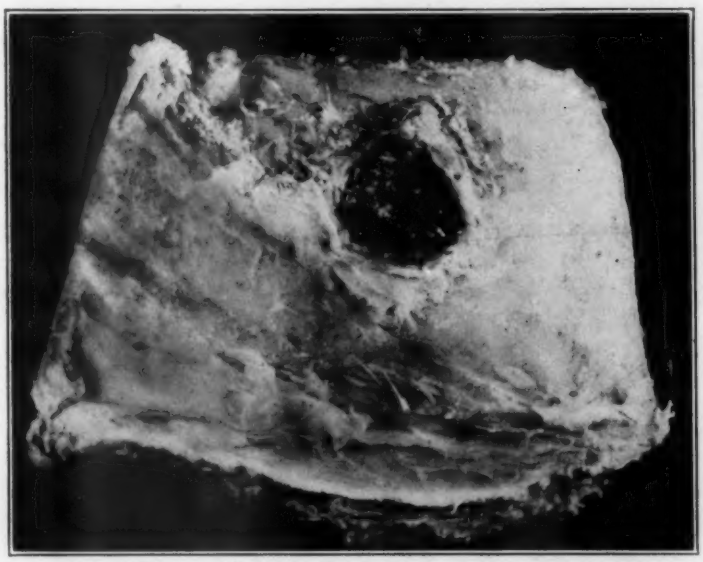

Fig. 21.—Magnesium disk in trephine opening in skull.

oval, at times occurring in two layers. There were many osteoblasts in growing areas and occasional included giant cells. The sinuses were moderately filled.

The predominating type of interstitial cell was relatively large and polygonal, with clear cytoplasm and rounded vesicular nucleus. There were many large polygonal cells with finely granular cytoplasm and round eccentric, relatively dense nuclei. The fat cells were few, small, clear and distended.

Zone 2: The bony trabeculae were thin and anastomotic, and the laminated structure was well defined. There were a few budding projections of new bone. The included bone cells were small and oval.

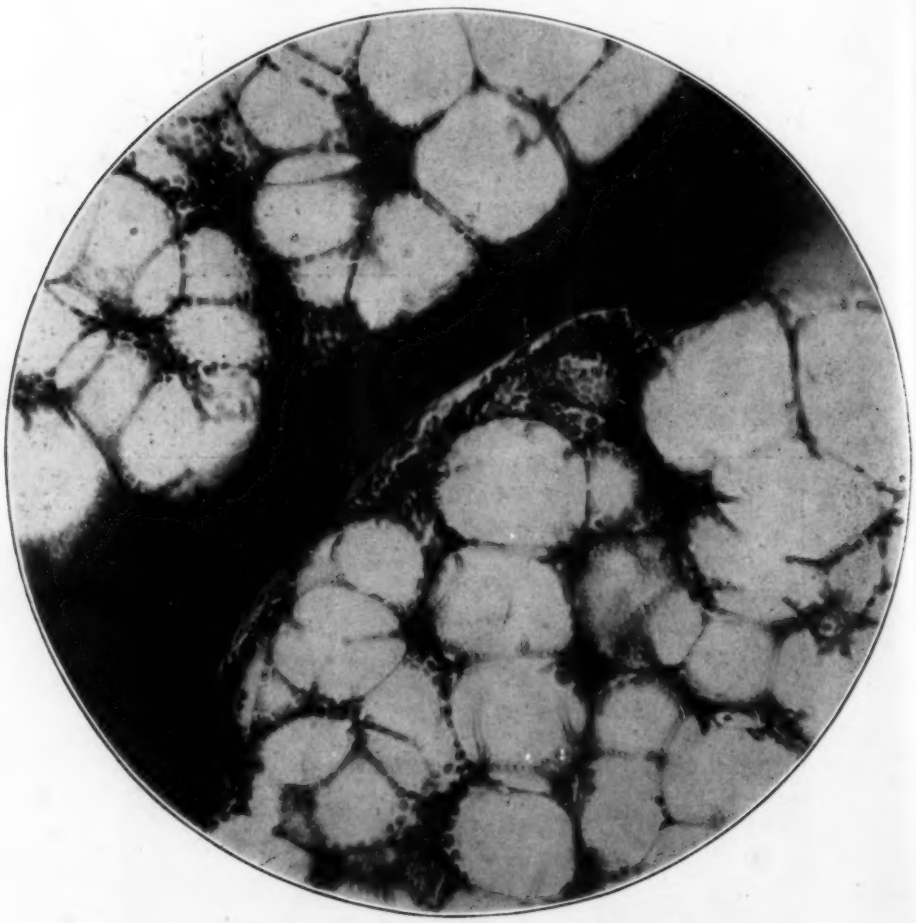

Fig. 22.—Normal cancellous bone.

The endosteum was of a thin single layer of cells with elongated dense nuclei. There were a few giant cells. The fat cells were few, small, clear and distended. The sinuses were moderately congested with red blood cells. The interstitial cells were the same as Zone 1, except for a few large, irregular cells, with coarse granules and eccentric, relatively dense round nuclei.

Zone 3: This was similar to Zone 2, except for the interstitial cells, of which many were irregular, polygonal cells with clear cytoplasm and large

oval vesicular nuclei. Also there were many irregular cells with finely granular cytoplasm and round, relatively dense nuclei and a few large irregular cells with large, coarse granules and eccentric round, relatively dense nuclei.

Silver.—Zone 1: The implant was surrounded by a closely applied, dense zone of spindle shaped connective tissue cells arranged in several layers. The bony trabeculae were thin, short and anastomotic with many budding projections of new bone, in which the lamellar structure was not defined. There

Fig. 23.—Cancellous bone about region of gold implant.

were many large, isolated bone cells and many budding processes with numerous osteoblasts and occasional giant cells.

The endosteum consisted for the most part of a single layer of cells, slightly larger and more nearly oval than normal. In places, two layers of cells were found. The fat cells were few in number, small and distorted, but clear. The sinuses were engorged with red blood cells.

Of the interstitial cells, the predominating type was fusiform, with an oval dense nucleus. A number of polygonal cells with clear cytoplasm and rounded vesicular nuclei and a few red blood cells were noted.

Zone 2: The bony trabeculae were thin and anastomotic, and the lamellar structure was defined. Isolated bone cells occurred in normal number, elongated and oval.

The endosteum was of a thin single layer of cells, with elongated dense nuclei. The fat cells were small, clear, distorted and not numerous. Of the interstitial cells, the predominating type was large and polygonal, with clear cytoplasm and a round dense nucleus. Also there were a number of polygonal cells, with finely granular cytoplasm and round dense nuclei.

Fig. 24.—Cancellous bone about region of aluminum implant.

Zone 3: This was normal.

Gold.—Zone 1: The implant was surrounded by three and four layers of concentrically placed connective tissue cells having an elongated, fusiform, fibrillar form, and elongated relatively dense nuclei.

The trabeculae were for the most part thin, but with a few thick budding areas. The anastomotic laminated structure was defined by additions of new bone. The isolated bone cells were relatively small and elongated. There were

budding processes of new bone covered with a single layer of osteoblasts. New bone was in close contact with the implant in many places. There was an occasional giant cell to be seen.

The endosteum for the most part was made up of a single layer of fusiform cells with elongated nuclei, but about the new bone there was either a single layer of young cells or in places a double one. A few included giant cells were to be seen in the thicker new trabeculae.

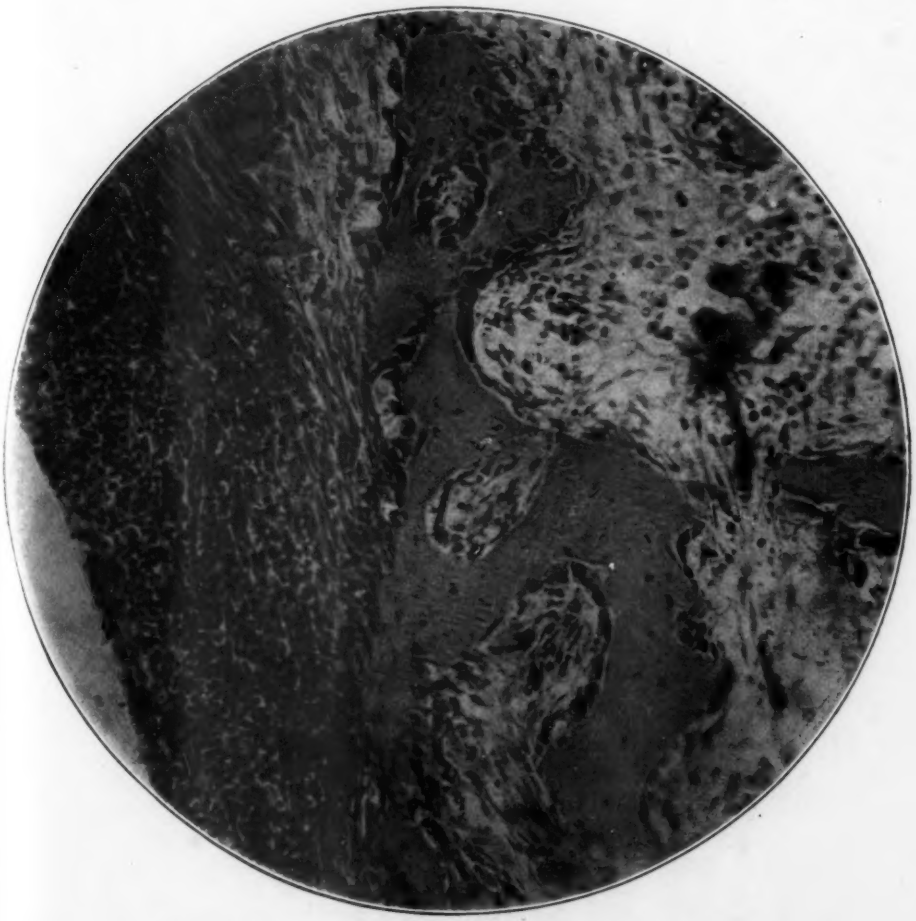

Fig. 25.—Cancellous bone about region of copper implant.

The fat cells were clear and distended, but fewer and somewhat smaller than normal. The sinuses were engorged with red blood cells.

The interstitial cells were chiefly large, polygonal or elongated cells, with clear or finely granular cytoplasm and rounded vesicular nuclei. A few normal red blood cells were to be seen.

Zone 2: The trabeculae were thin and anastomotic, and the laminated structure was defined. The isolated bone cells were fusiform, and there were no budding growths or new bone layers.

The endosteum consisted of a thin, single layer of closely applied cells, with elongated dense nuclei. The fat cells were clear and distended, but slightly smaller and less numerous than normal. The sinuses were engorged with red blood cells.

The interstitial cells were made up of a few large cells with a finely granular cytoplasm and relatively dense nucleus, and a few red blood cells. The pre-

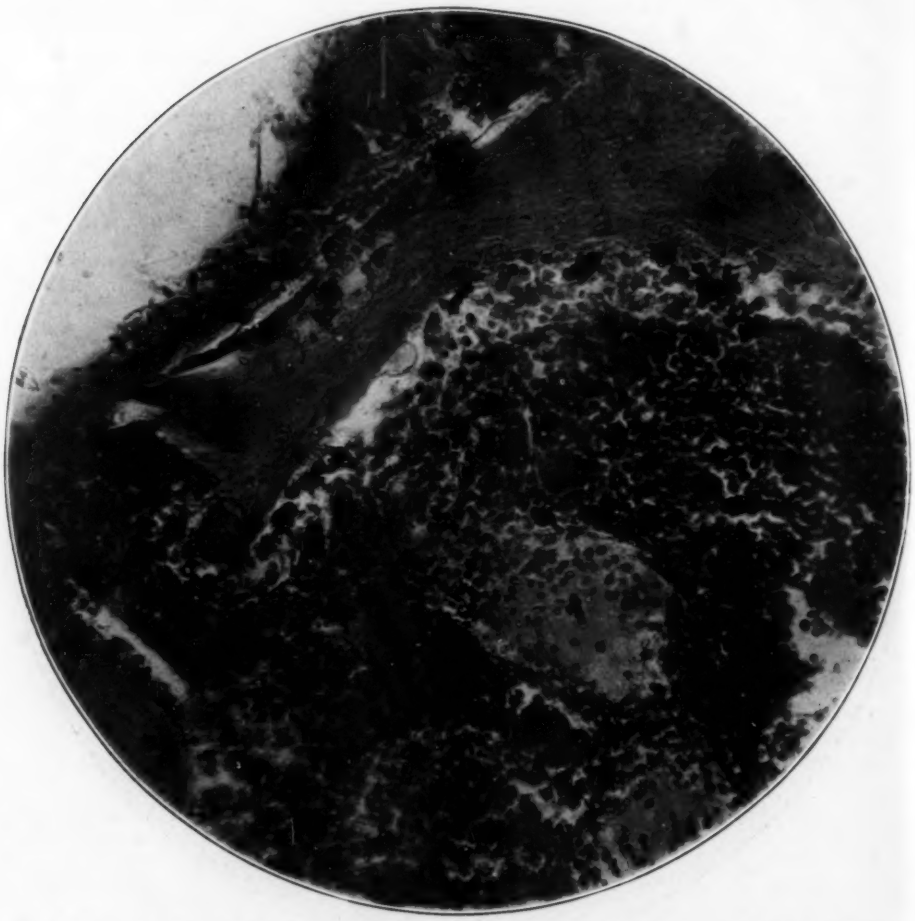

Fig. 26.—Cancellous bone about steel implant, showing pigmented giant cells.

dominating cell type was large with clear cytoplasm and oval or rounded vesicular nucleus.

Zone 3: This was much the same as Zone 2, except for the fat cells, which were larger and more numerous; also the sinuses were less noticeably engorged, and the interstitial cells had a few polymorphonuclear forms.

Copper.—Zone 1: The implant was surrounded by a thick concentric layer of spindle cells with dense elongated nuclei. The trabeculae were thickened and had many budding projections. The lamellar structure was not well defined and there were many large included bone cells.

The endosteum was thick and consisted of single and double layers of large cells, with oval vesicular nuclei. There were numerous giant cells in this region; but for the most part, the cellular tissue was made up of fibroblasts in various developmental stages, together with a few polymorphonuclear leukocytes and a few red blood cells. There were no fat cells present.

Zone 2: This region was very similar to the first, differing only in degree. The predominating type of interstitial cell was large and polygonal, with a

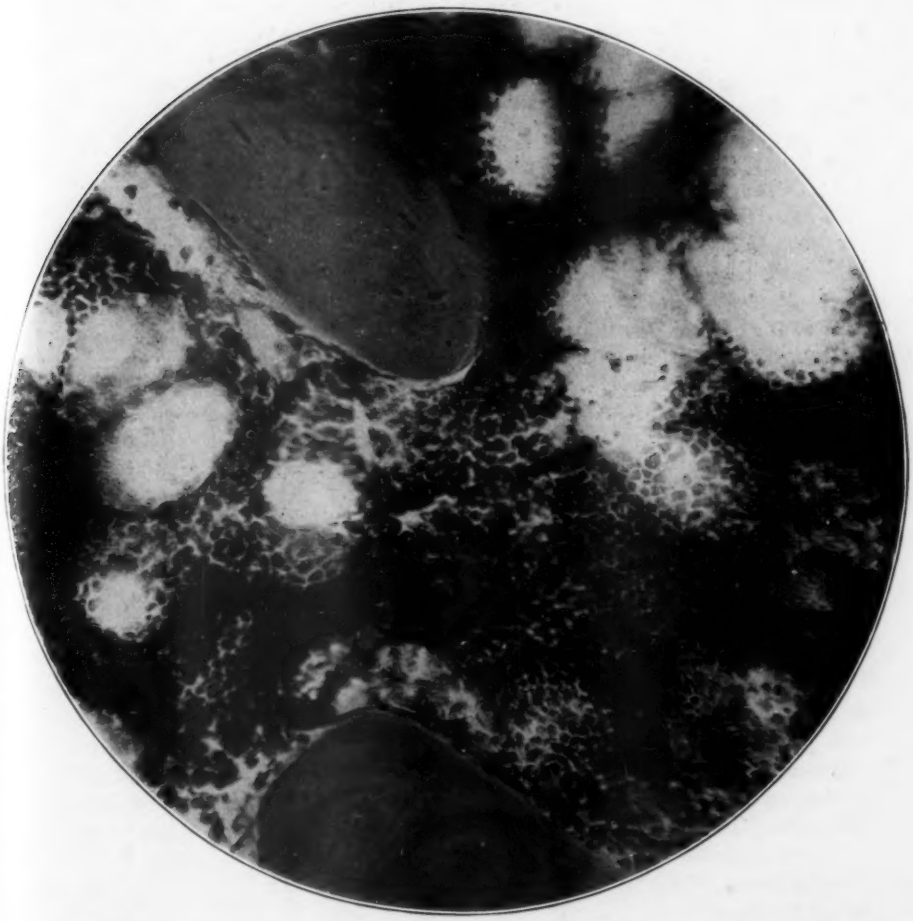

Fig. 27.—Normal repair of cancellous bone; site of injury in control specimen.

finely granular cytoplasm and a large eccentric, relatively dense nucleus.

The fat cells were few in number and were shrunken, deformed and cloudy. The blood sinuses were engorged with red blood cells.

Zone 3: The trabeculae were normal, but the interstitial marrow cells appeared smaller than usual.

Normal Bone.—The trabeculae were of definite lamellar structure with included fusiform bone cells.

The endosteum was closely applied usually in one thin layer of cells with elongated dense nuclei. Occasional giant cells and a few osteoblasts were seen. Fat cells were numerous, large, clear and distended. The sinuses were filled with adult red blood cells. The interstices between the fat cells were filled with masses made up of large, irregular and polygonal cells, with pale finely granular cytoplasm and a rounded eccentric, vesicular nuclei; small polygonal cells with clear cytoplasm and large round dense nuclei, and large irregular cells with coarsely granular cytoplasm and an eccentric vesicular nucleus.

Control.—Zone 1: The regenerating area showed the new bone trabeculae in shorter fragments than normal and not anastomotic. The lamellar structure was not definite and there were many large polygonal included bone cells. The endosteum consisted of single and of double layers of large cells with vesicular nuclei. The budding ends of the trabeculae showed many osteoblasts and a few giant cells. The fat cells were fewer and smaller than normal, and the sinuses were engorged with red blood cells. The interstices were crowded with marrow cells, chiefly of the large finely granular type.

Zones 2 and 3: These were normal.

Stellite.—Zone 1: The implant was surrounded by a dense, narrow ring of connective tissue.

The trabeculae of bone were similar to those surrounding the regenerating area in the control, but thinner and anastomotic. The included bone cells were moderately sized and oval. There were numerous budding processes of new bone covered with osteoblasts.

The bony network closely approximated the connective tissue sheath of the implant.

The endosteum was relatively thin and inactive except at the points of new growth.

Fat cells were present, clear and distended, but slightly smaller than normal. The sinuses were engorged with red blood cells.

The interstitial cells occurred in masses of the same nature as the control. The predominating type of cell was large and nongranular, although smaller ones were present as well as some coarsely granular.

Zones 2 and 3: These were normal.

Low Carbon Steel.—Zone 1: The implant was surrounded by a loosely arranged zone of connective tissue made up of oval and fusiform cells. Interspersed were numbers of large cells with clear cytoplasm and eccentric nuclei together with a number of giant cells which reacted to a special stain for hemosiderin. These giant cells were chiefly in the region of the implant, although a few were scattered through the tissue as far as the second zone.

The trabeculae were less in evidence than in the control. There were few budding areas of new growth and the endosteum was thin and inactive. No fat cells were present.

Zone 2: This region was normal except for a decrease in the size and number of fat cells and a slight excess of the connective tissue type of marrow cell.

Zone 3: This was normal.

SUMMARY AND ANALYSIS OF FINDINGS

In an analysis of the foregoing observations, it is obvious that a too minute scrutiny of all the variable factors involved will lead to confusion and a loss of the points at issue. The normal variation in

the reaction of living tissue is great, and this is magnified by the inability exactly to repeat experimental conditions.

The macroscopic findings in the control specimen of Series I exhibit the phenomena of normal reaction to injury. The wound of the skin and underlying soft tissues presents the usual evidences of repair.

The scar tissue is not extraordinary in amount or extent. Inspection of the same tissues in the remaining specimens of the series reveals a marked uniformity in behavior. In the control specimen, the site of the bone injury is merely a smooth white swelling. This condition is approximated by only five members of the series; those bearing gold, stellite, silver, lead and aluminum. These vary slightly among themselves, but the variation is well within normal limits. In the remainder of the series, there is evidence that the implanted metals definitely interfere with the usual process of regeneration. Discoloration of the surrounding tissues, crater-like depressions in the protuberances over the implants, or frank failure to cover the metal, occur singly or together as in the case of high carbon steel, low carbon steel and aluminum-bronze specimens.

The copper specimen, while badly discolored, instead of showing an intolerance to the metal, exhibits a marked overgrowth of the region. So great was the reaction that the experiment was repeated in two other animals in order to observe the constancy.

The microscopic studies of these specimens, as might be expected, afford a far better basis for conclusions than mere gross inspection. The slight swelling at the site of the drill hole in the control tibia is seen to consist of a slightly thickened periosteum and a mass of new bone; a crescentic periosteal portion blending with the endosteal growth from the cortical defect. In the medulla may be seen the trabeculae of new bone formation.

In establishing this control, several animals were employed, although only one is reported in the protocol. It was found that in all cases the character of the reaction was the same, the variation lying in the degree.

The medullary reaction and that from the cortical defect were constant and uniform, but the thickness of the layer of new subperiosteal bone exhibited a variability of 20 per cent. of the recorded specimen.

The section from the stellite implant shows the least departure from the normal. The type of reaction is similar and the degree is not outside the limits observed in the controls. Moreover, the new bone is so closely laid down about the metal that if a corresponding area should be blotted out of the control section, they could not be identified. In fact, it appears in this section that the metal merely occupies space, affecting in no way the regeneration of the bone and periosteum.

Very much the same picture is presented by the gold, silver and aluminum sections. The subperiosteal growth is somewhat excessive and the new bone does not conform to the outline of the metal quite so accurately, but these differences are very slight.

The section from the region of the lead implant is much like those previously mentioned, the chief difference occurring in the failure of the bone completely to cover the external end of the implant. Also, the encapsulation of the metal tends to be rather one of fibrous connective tissue than of bone.

In the case of the zinc implant, the failure of the subperiosteal bone and the new bone of the cortical defect to cover the implant is marked, and may be identified as the central depression noted in the gross. Although there is no attempt at bony encapsulation, there is a distinct fibrous connective tissue envelope about the metal and little evidence of actual tendency to extrusion.

In the magnesium section, the process is carried a step farther in that the enveloping connective tissue is more cellular and thicker. As compared to the zinc section, the new connective tissue is more in evidence than the new bone. Here again the trend is toward fibrous tissue encapsulation, with but indifferent response from the bony structures.

The copper, aluminum bronze and nickel specimens, while grossly dissimilar, should really be classed together, as they present in different measures the phenomena of irritation and stimulation.

The copper section is unique in that it is the only one which shows excessive overgrowth of bone and bony encapsulation of the implant. In this section, the medullary bone is more dense and more uniform than in any other, while the subperiosteal growth is tremendous. Even the cortex in the region of the defect, with its enlarged haversian canals, takes on the appearance of the surrounding newer structure.

In the periphery may be seen several areas of cartilage, the significance of which is difficult to determine, and which might be attributed to the stimulation of the copper. In a way, the section appears as a process of inversion to the embryonic type of bone.

In the nickel section, while the stimulation is evident, it is not so intense and falls short of a bony encapsulation of the metal. From the space about the implant and the amount of cellular tissue surrounding it, it may reasonably be concluded that the process is a slower one than that of copper. In all events, there is evidence of irritation and marked reaction of the tissue.

The aluminum bronze section, while classed with the copper and nickel sections, resembles them only slightly. The stimulation to the medullary bone growth is marked, and the bone of the cortical defect is relatively dense, but the subperiosteal growth is well within normal limits. Moreover, there is neither bony nor fibrous tissue

encapsulation of the metal, the region of the implant being a wide open V. Stimulation there undoubtedly is, but not in sufficient degree to insure the retention of the metal.

The steels and iron have been left for separate consideration in that they have some phenomena peculiar to themselves alone. The iron section shows an implant surrounded by a relatively thick fibrous tissue layer in which are giant cells showing brown to hematoxylin and eosin and staining deeply with a specific hemosiderin stain. These cells lie near to the metal and are not scattered through the surrounding tissue. The medullary bone and the bone of the cortical defect are rather dense and uniform, and the subperiosteal bone is well within normal limits. There is no tendency to overgrowth and no tendency to bony encapsulation of the metal; while the regenerative process is not stimulated, neither is it greatly interfered with.

Both high carbon and low carbon steel, when implanted in bone, provoke the same type of reaction. The metal is incompletely surrounded by a thick zone of cellular connective tissue, its outer end free and uncovered by any periosteum. In this connective tissue and for a short distance in the surrounding tissue are to be found many giant cells staining specifically for hemosiderin. The new bone production in the medulla is negligible; while in the cortical defect it is more scanty than in any of the other specimens, failing to approach the metal by a considerable distance.

The second series of experiments, although not of considerable value in determining the relative merits of the various implants, exhibits some interesting features which may aid in the analysis of other similar work. The intent was to employ the ribs of a dog in the same manner as the tibiae and compare the findings of the two different types of bone. The technical difficulties made this impossible, as the maintenance of the same proportion between metal and bone and the use of a piece of metal sufficiently large to be workable was often followed by fracture.

Examination of the gross specimens revealed, as was noted in Series I, a similarity in reaction between the control and the gold, silver, aluminum and stellite implants, all manifesting only a moderate fusiform enlargement at the site of injury.

The iron specimen was also of this character, but the bone surrounding the tissue is discolored.

Copper implantation, as in Series 1, was attended by a marked fusiform enlargement of the region with also the same discoloration.

The high carbon and low carbon steels, together with the copper aluminum alloy and nickel, all gave evidence of their irritant qualities by appearing uncovered by periosteum and accompanied by little bone stimulation.

The striking elements of the series lie in the behavior of the zinc, lead and magnesium implants, in that in these specimens the bone was fractured at the site of operation and all evidenced a large fusiform bony growth at this point quite in contrast to the reactions observed in the tibiae.

The third series of experiments involved metal implantations in the cancellous structure at the ends of the femora and was undertaken to determine the early stages of reaction in a very sensitive medium. In this way, it was thought that the more strongly stimulant or toxic metals could be grouped. Gross examination of the necropsy material revealed little except for discoloration of the implanted regions; the joints, capsule and overlying tissues showing the usual scar formation of a recent wound.

The control, the gold, the aluminum and the stellite specimens exhibited slight degrees of discoloration, and over the implant in each was found a thin layer of dense connective tissue. The silver specimen was similar but for a somewhat more marked discoloration.

The magnesium and iron implants also caused a moderate discoloration, but the ends remained uncovered by any tissues. This latter observation was made in the remainder of the series of which each was markedly discolored.

As in the first series, the gross evidence is not comparable to the histologic, serving merely as a rough means of classification. The microscopic studies are attended by considerable difficulties of which the technical are by no means the least. The tissue involved is, briefly, a network of bony trabeculae interspersed with marrow substance. To obtain bone sections sufficiently thin to allow of satisfactory study of the marrow cells, and yet of a thickness that would serve for orientation, proved a task which ended in compromise. The finer cell structure was sacrificed in order that the relationships of the various parts might be maintained, and as a result the recorded findings merely enumerate the general classification of marrow cell types without attempting a finer division, which is difficult even with film preparations.

In entering on the discussion of a subject so obscured by conflicting opinions, it is not only advisable but also necessary that some arbitrary standard of classification and nomenclature be adopted.

Accordingly, the catalogued observations have been made as much as possible in keeping with Carnegie Dickson's [28] monograph on the bone marrow. In this, he has identified cells of the following orders:

I. Leukocyte Series.
   A. Nongranular cells.
      1. Large.
      2. Small.

28. Dickson: The Bone Marrow, London, Longmans, Green & Co., 1908.

B. Granular cells.
   1. Neutrophil
   2. Eosinphil myelocytes.
   3. Basophil

II. Hemoglobin Series.
   A. Normoblasts.
   B. Megaloblasts.

III. Giant Cells.
   A. Megakarycocytes.
   B. Polykaryocytes.

IV. Cells of the Connective Tissue Type.
   A. Fat cells.
   B. Reticulum cells.
   C. Various phagocytic cells.
   D. Ordinary connective tissue cells.

V. Endothelial Cells.

Examination of the section of normal bone in the region of the femoral epiphysis reveals a network of adult bone trabeculae covered with a thin, inactive endosteum. Fat cells are numerous, large, clear and distended, and the blood sinuses are well filled with adult red blood cells. The interstices between the fat cells are filled with masses of large and small nongranular cells, also large cells of the granular type; all of the leukocytic series. Occasional giant cells, or polykaryocytes, are to be seen, with a few osteoblasts.

In the control specimen, the greater part of the section is identical with the character of normal bone; but the immediate zone of the injury exhibits an active process of repair.

The new bone appears in short nonanastomotic fragments, and the endosteal covering consists of single and double layers of osteoblasts, and about the budding ends of the trabeculae are a few giant cells. The blood sinuses are large and crowded with red blood cells, but the fat cells are few and smaller than normal, although clear and distended. The interstitial marrow cells are present in larger masses than in normal bone and consist chiefly of the large nongranular type.

All this is quite in keeping with our conception of reparative processes elsewhere, the unique feature being the increase in marrow cells. However, this too is to be expected, as Dickson found the quantity of fat present to vary inversely with the activity of the tissue.

As in the first series, the specimens bearing the aluminum, gold and stellite implants may be grouped together for consideration, their individual differences being slight and chiefly of degree rather than quality. In each, the metal is surrounded by a dense zone of connective tissue of three or four layers, closely approximated by new bone. Peripherally from this point, the changes are well within the limits of the normal reaction as shown in the control.

Next in order of variance comes the magnesium specimen. In this, the connective tissue zone surrounding the metal is slightly more cellular and more loosely arranged, as well as being definitely thicker. Thicker, too, and more actively proliferating, are the bony trabeculae. This change extends well into the intermediate zone, the extreme periphery being normal.

Proceeding further on the scale of activity, the implants of silver, lead and zinc range themselves in a closely related group. The bone proliferation in each is somewhat in excess of normal and the stage of regeneration seems farther advanced.

Moreover, while the zone of greatest departure from the normal is that in the immediate vicinity of the metal, it definitely extends into and involves the surrounding area. The interstitial marrow cells are of the granular and nongranular types, with a few polymorphonuclear forms. Throughout the primary zone, and to a lesser degree the secondary zone, are found numerous cells of the connective tissue type, of which very few were present in the control. The most interesting change occurs in the fat cells, which are shrunken and cloudy, and apparently degenerative forms. This condition is probably of the same nature as that described by Bizzozero,[29] Jackson,[30] Neumann [31] and others. It occurs again in more marked degree in other sections, notably the copper, and may be considered a degenerative process similar to that occurring in toxemias and in starvation.

In the case of the aluminum bronze and nickel implants, this same excess of connective tissue is to be seen, but the bony regeneration is less marked. The reaction extends from the site of the implant into the secondary zone, where it is less notable; also the fat cells are absent in the primary zone and only slightly affected toward the periphery. The entire process is an attempt at repair into which the bone does not enter to the degree manifested in the control.

In many respects, the condition is similar to the fibrous marrow resulting from chronic disease processes, as noted by Dickson. The connective tissue element is probably derived from the reticulum cells described by Jackson.

In the copper specimen is seen the most marked reaction of the series. The bone and connective tissue proliferation are equally exaggerated at the expense of the fat cells and the blood cells of the marrow. The activity extends well toward the periphery and even at some distance from the implant, the fat cells occurring in degenerating forms.

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29. Bizzozero: Quoted by Dickson, p. 73 (Footnote 28).
30. Jackson: Arch. f. Anat. & Physiol., 1904, p. 33.
31. Neumann: Centralbl. f. d. med. Wissensch. **20**:321. 1882.

Throughout the greater part of the section, there is evidence that the tissue has been stimulated to a tremendous activity.

The specimens bearing the iron and steel implants present phenomena very like those exhibited in the sections of the tibiae. In all, the implant is enveloped by a relatively thick layer of connective tissue surrounding which are the pigment giant cells. As noted before, these occur in greater numbers about the high carbon and low carbon steels, the iron apparently being less easily affected.

Again, as in the previous series, bone proliferation in the steel sections does not equal that of the control; while in the iron specimen, it falls quite within normal limits. In these three metals of the three series, the relative variation of the iron is much less than in the previously described Series 1.

Concerning the last two series of experiments, little, if anything, need be added to the recorded observations. In Series IV, the reaction is chiefly one of connective tissue, and the results obtained are sufficiently obvious to require no further amplification. This also is true of the roentgen-ray findings of the last series, wherein the degree of callous formation can be definitely measured from the photographs. It would be well not to attach too great importance to the subperiosteal bone so frequently found opposite the implant in this series, as Gazzotti's [32] experimental work would seem to show that the necessary extensive elevation of the periosteum over the circumference of the bone would in itself be sufficient cause for the subperiosteal growth.

From the foregoing review of the findings, it may be observed that, in the different types of tissue examined, there is a uniformity at least in the manner, if not in the degree, of reaction to the various metal implants, except in the second series involving the ribs. Here, fracture of the bone at the point of injury has added a new and modifying factor in the mobility of the parts, and it is well to note that each instance of fracture is attended by an excessive bony overgrowth, which does not correspond to the findings in the other series. Consequently, it may be taken that the movement of the part is responsible for the bone stimulation, and not the presence of the metal. This may serve to explain the findings of Groves,[27] who noted excessive bony overgrowth when magnesium intramedullary pegs were used in experimental fractures, as in these cases the absorption of the metal early allowed considerable mobility to the parts.

Excluding this first rib series as untrustworthy and technically defective, the remaining experiments constantly present one set of facts: Bone is indifferent to the implantation of some metals and sensitive to

32. Gazzotti, L. G.: Policlinico (sez. chir.) **25**:129 (May) 1918.

others. In the first group the metal remains unchanged during its placement in the tissue; while in the second group, there is definite evidence of varying degrees of corrosion. All other experimental factors being uniform, the only conclusion permissible is that the tissue reaction depends to a great extent on the disintegration of the metal.

It must, of course, be recognized that the foreign body, purely as such, affects the reparative processes to some degree, but the findings in the foregoing bone sections show it to be much less marked than in the connective tissue elsewhere. The endothelial cell proliferation and giant cell formation noted by Mallory [33] is certainly poorly represented, although this might occur were the metal finely divided. Nor does it coincide fully with the observations of Herzog,[34] Marchand,[35] and others, in regard to the leukocytic infiltration, perhaps by reason of the disparity of the mediums and materials.

Le Fort's [36] observations on the tolerance of tissue to metallic masses, even though concerned with the soft tissues, coincide with the preceding observations on bone. He says: "When the mass is nonseptic, nonirritating by its anatomic location or form or chemical nature, the organism tends to ignore it and the phenomena of defense do not appear. The usual reaction is the encapsulation in a dense wall of fibrous tissue."

Therefore, when the reaction exceeds this and involves the more remote tissues, it must be by reason of something other than the mere presence of an inert foreign body.

It is axiomatic that, in mass form, a metal may modify other elements only at the expense of its own substance. In an electrolyte, this is accomplished by the dissociation of metallic ions, to the end that a colloidal solution is formed which conforms to the solution pressure of the metal. This process underlies the phenomenon which we term corrosion, and recently Friend [37] has advanced this idea as explaining changes in steel and iron exposed to the action of electrolytes.

Gold and platinum are known as noncorrosive metals and do not pass into solution in this way, as has been shown by Naegeli [38] and others. The same thing is claimed for stellite.

The preceding experimental series, however, have exposed the several metals to the action of living tissue wherein they are subject not only to the inorganic solutes, but also to their protein combinations.

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33. Mallory: Pathologic Histology, 1914, p. 52.
34. Herzog: Beitr. z. path. Anat. u. z. Allg. Path. **61**:325, 1915.
35. Marchand: Beitr. z. path. Anat. u. z. Allg. Path. **4**:38, 1888.
36. Le Fort: Bull. et mém. Soc. de chir. de Paris **44**:733, 1918.
37. Friend, A. M.: J. Chem. Soc. (London) **119**:932, 1921.
38. Naegeli: Denkschr. d. Schweiz. Naturforsch. Gesellsch. **33**:1, 1893.

According to Benedicenti [39] and Revello-Alves,[40] on shaking salt free albumin solutions with metallic iron, copper, lead, nickel or aluminum, portions of these metals go into solution and are bound by albumin in a masked or unrecognized form. Bechhold [41] also states that in the presence of salts, albumin forms, with heavy metals, precipitates whose chemical composition is not constant but depends on the concentration of the components at the time of precipitation. This gives intimation at least of the complexities which may arise from contact of metallic ions with living cells. Salus [42] believes the influence of metals on living cells to be preponderatingly destructive, but that in some instances it may be a growth stimulant.

Robin [43] believes the action to be only stimulative; while Naegeli [38] rather compromises the matter by saying that different cells react to different metals and in different manners.

Admittedly, there is much confusion, and the nature of the activity is not clearly understood; Baumgarten and Luger [44] and others holding fast to a purely chemical explanation; and Saxl,[45] together with many, claiming it to be a physical phenomenon.

But whatever the process, the experiments here recorded appear to bear out Naegeli's conclusions, the most notable examples being copper and high carbon steel, the former attended by an excessive bony overgrowth and the latter remarkable for its inhibitory action.

CONCLUSIONS

But few statements can be made beyond a catalogue of the individual reactions, as follows:

Gold, aluminum and stellite are readily tolerated by bone and tend to become encapsulated with but little hindrance to the reparative processes. They are inert materials, unaffected by the living cells and body fluids. This is contrary to the findings of Duval,[46] Elsberg [47] and Danborn,[48] who observed that aluminum was absorbed when planted in the tissues.

Silver and lead are only slightly less tolerable to bone, but are easily corroded and evoke a slightly greater connective tissue response.

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39. Benedicenti: Quoted by Bechhold, H., and Bullowa, J. G. M.: Colloids in Biology and Medicine, New York, D. Van Nostrand Company, 1919, p. 157.
40. Revello-Alves: Quoted by Bechhold, Footnote 39, p. 157.
41. Bechhold: Footnote 39.
42. Salus: Wein. klin. Wchnschr. **32**:1220, 1919.
43. Robin: Bull. Acad. de med. **68**:6, 1905.
44. Baumgarten and Luger: Wein. klin. Wchnschr. **30**:1224, 1917.
45. Saxl: Wien. klin. Wchnschr. **30**:1224, 1917.
46. Duval: Bull. et mém. Soc. de chir. de Paris **42**:611, 1916.
47. Elsberg: Proc. New York Acad. Med., April 6, 1906.
48. Danborn: Proc. New York Acad. Med., April 6, 1906.

Zinc goes into solution readily and causes a slight connective tissue stimulation. It also interferes with bone regeneration and does not become encapsulated by it.

Contrary to Grove's findings, nickel has a distinctly injurious effect on bone growth. It is soluble in the tissue, which makes little attempt to retain it.

Also opposed to Grove's observations are those regarding magnesium. In the experiments before mentioned, its behavior proves that it has little action other than as a connective tissue stimulant. If anything, it retards rather than accelerates bone production.

Copper causes definite stimulation to bone production, although being slowly absorbed. Some specimens suggest that it may be toxic to the tissue in the immediate vicinity, but an active stimulant at a distance.

Alloying copper and aluminum seems to perpetuate this toxic action but without its far-reaching irritant effect, for copper aluminum bronze frankly interferes with bone regeneration and tends to become extruded.

Steel and, to a less degree, iron definitely inhibit bone regeneration. Steel, which is poorly tolerated and readily soluble, seems least suitable of all for bone prosthesis.

FRACTURES OF THE FEMUR

WITH SPECIAL REFERENCE TO THE TREATMENT OF UNUNITED AND MALUNITED CASES BY MANIPULATION AND CALIPER EXTENSION *

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Before the World War the treatment of fractures of the shaft of the femur was always regarded as somewhat difficult, and some degree of permanent disability following this injury was not infrequently observed. The chief causes of disability were faulty alinement of the fragments and shortening, the latter being especially common. Pearson and Drummond in "Fractured Femurs" emphasize this point when they quote from Treves's Surgical Anatomy, 1915 edition, "Recovery without shortening of the affected limb was the exception." It was also customary to regard the result as fortunate if union in good alinement was secured without more than an inch of shortening. The results obtained, therefore, left much to be desired.

Methods varied considerably in detail and in the type of splint employed, but most surgeons agreed on the fundamental principles of treatment: namely, the provision of traction and counter-traction. The former was obtained by the application of adhesive plaster to the skin with weight and pulley attached, Buck's extension, while the latter was secured by elevating the foot of the bed and utilizing the body weight of the patient.

Though the results in civil practice were often unsatisfactory, it was the large number of cases occurring in the World War that created a real emergency and forcibly demonstrated the inadequacy of the existing methods of treatment. Adhesive tape could not be applied effectively in the presence of large wounds of the leg and thigh, and frequently it slipped and pulled off the skin over wide areas, making reapplication difficult or impossible. Furthermore, the prolonged immobilization of the knee and the stretching of the ligaments of this important joint made for a long and uncertain convalescence. The greatest objection to adhesive traction, however, was that it frequently failed to give the desired results, union with full length and normal alinement. The same objections to its use hold good today.

A great advance made during the late war was the introduction into more general use of a comparatively new principle: namely, direct traction on the bone, now commonly termed skeletal traction. This was

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obtained by the application of calipers to the condyles of the femur. It was a great improvement over the indirect or adhesive traction method because: (1) direct traction on the bone is mechanically sound, and experience proved that full length and good alinement can be obtained with uniformity; (2) the knee joint is free for active motion; (3) no strain is thrown on the ligaments of the knee; (4) the entire limb is left free for inspection, and adjustments can easily be made; (5) it can be applied effectively in the presence of large wounds of the thigh and leg, and (6) the axis of traction can be altered to meet requirements in fractures of any part of the shaft of the femur.

As in the case of adhesive traction, calipers were used in conjunction with various types of splints, but in my opinion the best method based on "nonpenetrating calipers" was that devised and practiced by Pearson at the Edmonton Hospital near London. He employed the Thomas splint to support the limb, and added a hinged flexion piece so that the knee could be moved during treatment. By suspending the leather ring firmly against the tuberosity of the ischium and fixing the lower end of the splint, he obtained a fixed counter-extension. The advantages of this form of counter-extension over that obtained by the patient's body weight are that it remains constant, thereby making traction more effective, and that it is much more comfortable for the patient. Another ingenious device of Pearson's was the screw pressure pad, which is fastened to the lateral bars of the Thomas splint; by means of a thumb-screw arrangement, lateral displacement of the fragments can be corrected. It can also be utilized to correct anterior posterior displacement when it is used with the half ring attachment as illustrated in Figures 1 and 2.

Anyone familiar with the results obtained by Pearson cannot fail to be impressed with the value of the method. In cases reported by him, recovery without shortening was the rule rather than the exception, and the early and complete restoration of function was a striking feature.

It was my good fortune to have the opportunity to utilize the Pearson method in the treatment of a considerable number of cases in Savenay, France, and, later on, to introduce the method in the service of Sir Harold Stiles at the Royal Infirmary, Edinburgh. The uniformity with which good results were secured convinced me that this was by far the best method for the treatment of fractures of the femur. I was, and remain, greatly impressed with the fact that it combines simplicity with great mechanical efficiency.

During my three and one-half years in the surgical service at the University Hospital, Ann Arbor, Michigan, I adopted the Pearson method with slight modifications as the standard form of treatment

Fig. 1.—Thomas splint and knee flexion piece suspended to the Morison overhead bed frame with caliper traction, with a patient on whom manipulation and refracture of the femur had been done. The method of suspension of the leather ring to secure fixed counter traction is clearly shown.

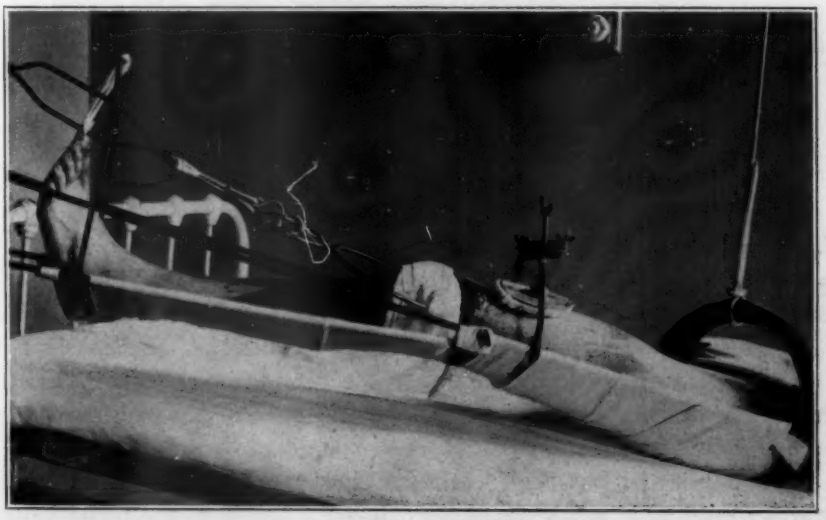

Fig. 2.—Closer view of the same apparatus, showing screw pressure pad attached to a half ring in order to correct anterior lateral displacement of the fragments.

in all cases of fractures of the shaft of the femur. Full length and correct alinement were uniformly obtained, and the results were so highly satisfactory that it was never necessary to resort to open operation in the recent cases of simple fracture. Compound fractures and nonunion due to the interposition of soft parts were the only indications that warranted such intervention. These facts are of even greater significance when one realizes that, in some clinics, operation on early fractures of the femur is frequently done, and that, by some surgeons, it is considered the method of choice. Notwithstanding opinions to the contrary, I regard open reduction of a recent simple fracture of the femur as a formidable undertaking, as well as an often unnecessary procedure. The dissection is prolonged and difficult, and the damaged tissue and blood clot offer an ideal field for infection. The number of cases of osteomyelitis of the femur due to open reduction is far too large to warrant its use except in rare instances. The fact that the Pearson method uniformly obviates operation is, to me, its greatest recommendation.

The question as to infection of the bone due to the use of calipers has often been raised, and, theoretically at least, this danger exists. It is true that in many of the cases a small amount of discharge is seen about the caliper points after they have remained in place for a few weeks, but the fact that these wounds heal promptly after the removal of the calipers, leaving a scar which is freely movable over the bone, has convinced me that infection is of no practical importance. In fairness, one must admit that the wound about the calipers may become infected from the outside, but in actual practice this is never of a serious nature, if the calipers have been introduced under the most rigid aseptic technic and through an incision that provides adequate drainage. Another point of importance is that frequent dressings should be avoided, for I am convinced that they greatly increase the possibility of infection.

A word of caution should be given in regard to the use of calipers in children. In the child, the lower femoral epiphysis has not united with the shaft and, if the calipers should slip, there is danger of separation of the epiphysis. This accident happened once in my experience, where calipers were employed to pull down the head of the femur in an old case of congenital dislocation of the hip. Since then, in similar cases I have made use of the Steinman pin inserted through the shaft of the femur well above the epiphyseal line.

To those who have had little experience with skeletal traction it might seem that it was more painful than traction obtained by adhesive tape. As a matter of fact, calipers are never painful unless they pull directly on the skin. This can be avoided if they are inserted correctly, a fact that will be pointed out in a later paragraph. I have made special

effort to inquire of patients who had had experience with both adhesive and caliper extension as to which was preferred, and, in every instance, they have preferred the caliper traction because it was not painful.

TREATMENT OF MALUNITED FRACTURES OF THE FEMUR

Malunion of the femur is generally regarded as a clear indication for operation, either an osteotomy alone or an osteotomy supplemented by traction being the procedure frequently adopted. Here I wish to make the point that, in the earlier cases, operation is not often necessary, and that another method is available which is much more simple and entirely reliable.

In the majority of malunited fractures seen early, a careful examination will reveal localized tenderness over the callus. This is found even in cases of several months' standing and is of the greatest importance to the surgeon, for it is definite evidence that the callus is still the seat of an active change, and that it has not yet reached the stage of complete consolidation. Sir Robert Jones, recognizing in this a basic principle of treatment, pointed out that manipulation under anesthesia would often accomplish refracture, and that if it were immediately followed by traction and counter-traction, faulty alinement could be corrected and the shortening greatly reduced. He has employed this method often, rather than operation, and it was my privilege to witness him carry out such treatment with striking success. In Savenay, France I had occasion to utilize this method frequently, and, without exception, great improvement in length and alinement resulted.

Since the war I have continued to use manipulation for refracture in malunion, but I have employed caliper traction in place of adhesive to insure complete restoration of length to the limb. Efficient traction is of greater importance in older than in recent fractures because, in addition to muscle contraction, we have shortening, which is fixed by callus and adaptive changes in the soft parts.

The results obtained by refracture and caliper traction have been very gratifying, for we have been able to overcome the shortening completely where the union was of from six weeks to four months' duration and in which there was as much as 3 inches (7.6 cm.) of overlapping. The patient is subjected to a short anesthesia and does not undergo the risks of a major operation.

Objection has been made to manipulation on the grounds that it may produce a fracture at a site other than the original one, particularly where disuse atrophy of the bone is pronounced. In my experience this accident has never happened, and I believe it can be avoided by selecting the cases exhibiting distinct tenderness of the callus, and carefully splinting the limb so that all the force is thrown directly on the site of the fracture.

The danger of nonunion following manipulation is a real one, especially in cases of overlapping fracture, where the ends of the fragments are sclerotic, and the medullary canals are completely closed by bone. I do not regard these findings, however, as a contra-indication for manipulation; caliper traction will give the necessary length, and the operation to secure union has been converted from a long and difficult undertaking to a comparatively simple procedure.

Case 3 (Figures 8, 9 and 10) is a typical example of an overlapping fracture with sclerosis of the ends of the fragments, in which manipulation and caliper traction completely reduced the shortening, but resulted in nonunion. Operation was necessary, but was greatly simplified because the overriding of the fragments had been corrected as a preliminary, and all that was necessary was the removal of sclerotic bone and the fixation of the bone ends with a beef bone plate. Union resulted, with only a three-fourths inch shortening.

The following paragraphs describe in detail the technic of (1) manipulation, (2) application of calipers and (3) the adjustment of the splint and traction to the Morison overhead bed frame.

TECHNIC OF MANIPULATION

A forty-eight hour preparation of the skin of the thigh and leg is a preliminary to manipulation. To avoid strain on the knee joint, padded board splints, extending from the site of fracture to the sole of the foot, are firmly bandaged to the lateral and posterior surfaces of the limb. Control of the upper fragment is secured by taking a hitch with padded rope just above the fracture. Under nitrous oxid anesthesia, with an assistant controlling the upper fragment by means of the rope, the operator quickly refractures by forcibly increasing the deformity. The fragments are further disengaged by internal and external rotations as well as by traction applied to the lower fragment. Often, lengthening of an inch or more can be obtained at this time. A Thomas splint with knee flexion piece attached is then applied, forcing the ring against the tuberosity of the ischium. The thigh and calf are supported by flannel bands fastened to the uprights of the splint.

APPLICATION OF THE CALIPERS

The skin of the lower thigh, knee and upper leg, is prepared with 5 per cent. trinitrophenol, and sterile dressings are applied. In order to avoid injury to the knee joint capsule and to secure the best purchase on the condyles, the rules laid down by Pearson are followed. The inner caliper point is placed just above and in front of the adductor tubercle, while the outer is placed in the same horizontal plane and directly in front of the iliotibial band. When these landmarks are defined, the skin is pulled upward, and stab incisions are made down

to the bone on both sides. The caliper points are driven into the bone to the depths of about one-fourth inch. Releasing the traction on the skin allows it to lie loosely below the points, and herein lies the secret of painless calipers. Gauze dressings, saturated in trinitrophenol, are wound securely around the caliper points.

ADJUSTMENT OF THE SPLINT AND TRACTION TO THE MORISON OVERHEAD BED FRAME

For overhead suspension in fracture treatment, we are using the portable frame designed by Robert Morison, sanitary engineer of the Royal Infirmary, Edinburgh (Figures 1 and 2). It is constructed of gas pipe with attached tubal arms that can be moved up and down or can be rotated on the uprights. This feature allows flexion, abduction and adduction of the limb without altering the position of the patient. The frame is simple and permits easy and quick adjustments.

To adjust the patient to the frame a rope is attached to the anterior half of the Thomas ring, and the free end passed over two pulleys on the horizontal bar. To this free end, sufficient weight is attached to hold the ring firmly against the tuberosity of the ischium. The advantage gained by such an arrangement is that when the patient raises himself from the bed, the ring of the splint continues to hug the ischial tuberosity, and a constant counter-extension is maintained. The lower end of the splint is fixed to a horizontal tubal arm, and traction is obtained by weight and pulley attached to the calipers (Figs. 1 and 2).

The average weight necessary is about 30 pounds (13.6 kg.), and this is maintained until the injured leg is actually longer than its fellow. This usually requires from ten to fourteen days. Lateral displacement is corrected by the screw pressure pads (Figs. 3, B and 12, B). When accurate alinement is secured, the weight is decreased until the ends of the fragments are apposed, and this position is held securely until union has taken place as shown by clinical examination and roentgen-ray plates. The time required is usually about ten weeks.

Pressure sores beneath the Thomas ring are evidence of failure to care for the leather and the skin with which it lies in contact. They can be avoided by changing the area of the skin pressed on at frequent intervals during the first few days of traction, and by carefully washing and drying the leather ring at least twice daily.

REPORT OF CASES

The following cases are illustrative of the results obtained by the method:

CASE 1.—*History.*—J. G., a farmer, aged 47, entered the University Hospital, Dec. 16, 1920, complaining chiefly of inability to walk following a fracture of the left femur. Oct. 28, the patient had fallen from a haystack, sustaining a fracture

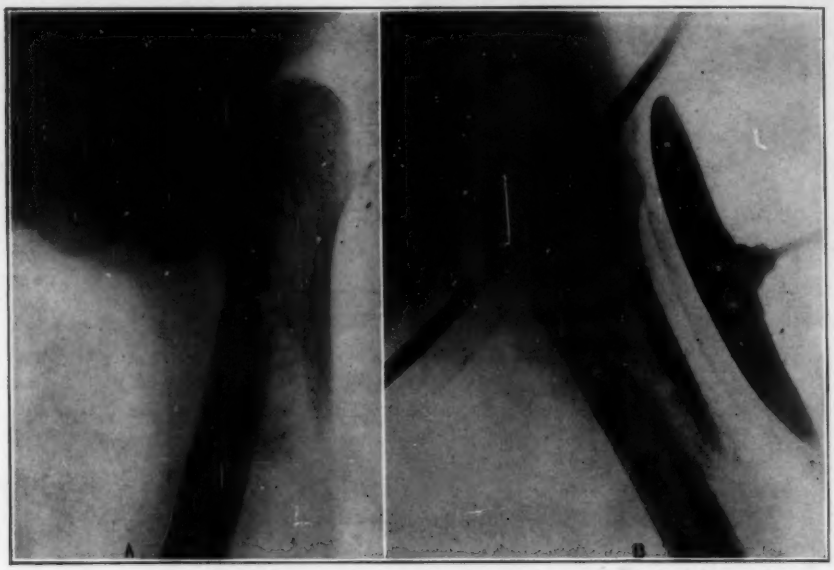

Fig. 3 (Case 1).—*A*, position of fragments on admission, showing angulation and overlapping with callus formation; *B*, after manipulation and application of pressure pad.

Figure 4

Figure 5

Fig. 4 (Case 1).—Final result, with union in good alinement.

Fig. 5 (Case 2).—Appearance of fracture on admission (Feb. 2, 1921), showing union with displacement of the fragments.

of the left femur. Immediately after the injury, the limb was immobilized and traction applied by means of adhesive tape. After six weeks, it was found that deformity remained, and he was sent to the hospital for further treatment.

Physical Examination.—Examination revealed a fracture of the middle third of the left femur with a marked lateral bowing. There was union of the fragments with an inch (2.5 cm.) of shortening. Tenderness was present over the site of the fracture, and there was pain on manipulation. The blood Wassermann reaction and the urine examinations were negative. A roentgenogram, Dec. 16, showed a spiral fracture of the left femur, with marked angulation of the fragments and some callus (Fig. 3 *A*).

Operation.—December 23, manipulation and refracture were done, followed by traction on the lower fragment. The limb was immobilized in a Thomas splint, and a pressure pad was applied to correct the lateral bowing. The roentgen-ray examination, Jan. 6, 1921, showed a satisfactory reduction and good alinement of the fragments (Fig. 3, *B*). Immobilization was continued until Feb. 21, when union was solid. A walking caliper splint was applied, and the patient was discharged from the hospital Feb. 25.

April 1, the patient returned and the examination showed union, with full length and good alinement. The roentgen-ray examination (April 1) gave evidence of satisfactory reduction with bony union (Fig. 4).

A letter received from the patient May 10 stated that he was highly pleased with the result obtained, and that he was walking without any limp. There was free motion of the knee, he was working as usual, and was able to drive his car.

CASE 2.—*History.*—K. W., a school-boy, aged 15, entered the University Hospital, Feb. 5, 1921, complaining chiefly of a deformity following a fracture of the left femur. Nov. 3, 1920, the patient had fallen while playing football, and sustained a fracture of the left femur. He was treated with Buck's extension and coaptation splints for a period of six weeks, and then the limb was immobilized in a plaster of Paris cast.

He entered the hospital because of pain in the region of the fracture, and because of a marked internal rotation of the foot.

Physical Examination.—The left thigh showed a moderate atrophy and thickening in the region of the great trochanter. There was an inch (2.5 cm.) of shortening. Pronounced internal rotation of the lower fragment was present to such an extent that the foot could not be rotated to a vertical position. The roentgen-ray examination, Feb. 2, 1921, revealed a fracture just below the lesser trochanter, with overlapping of the fragments and the evidence of bony union (Fig. 5).

Operation.—Feb. 8, 1921, manipulation with refracture and the application of calipers to the condyles of the femur were done. A Thomas splint was applied and fixed to the overhead frame. A 20 pound (9 kg.) weight was attached, and two pressure pads fixed to the lateral bars of the splint to correct inward displacement of the upper end of the lower fragment.

Feb. 22, 1921, the roentgen-ray showed correction obtained by traction and pressure pads. There was a normal alinement with slight separation of the ends of the fragments (Fig. 6). The calipers were removed March 20, and the caliper wounds were healed in ten days. April 27, the union was quite firm with good alinement, and the patient was allowed to get up, making use of a walking caliper splint. The final examination, July 20, 1921, showed three-fourths of an inch (19 mm.) of lengthening, with solid union. The patient walked without any limp.

The roentgen-ray, July 20, revealed the final result to be bony union with good alinement (Fig. 7). A letter received from the patient several months after his last examination stated that he was in a training camp, and that he was able to carry on the usual routine without either discomfort or disability.

CASE 3.—*History.*—C. G., aged 24, entered the University Hospital Oct. 23, 1921, complaining of marked shortening, following a fracture of the left femur.

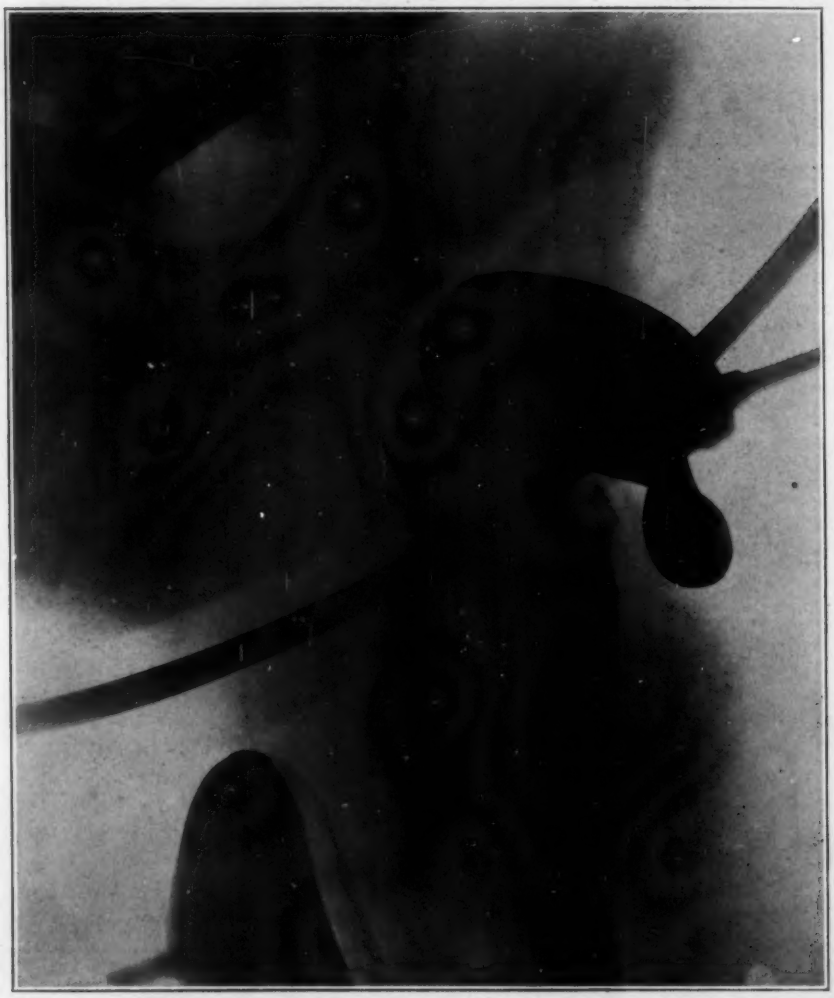

Fig. 6 (Case 2).—Position of fragments after manipulation (Feb. 22, 1921), caliper traction and pressure pads. Correction of lateral displacement may be noted.

July 4, the patient had been in a train accident, sustaining a fracture of the left femur. For a period of eight weeks he was treated by adhesive traction and fixation of the limb with sand bags. He was then allowed to walk without support, but there was a pronounced limp, and the left leg was noticeable shortened.

Examination.—The examination revealed some wasting of the muscles of the left thigh, with a moderate degree of lateral bowing at the middle third of the femur. There was definite tenderness over the callus, and measurement proved that there was a 3 inch (7.6 cm.) shortening. Union was quite firm. The Wassermann reaction on the blood was negative, and the urine examination was negative.

Fig. 7 (Case 2).—Appearance of bone, July 20, 1921, five months after manipulation, with good alinement and solid bony union.

Oct. 19, the roentgen-ray revealed a fracture of the middle third of the femur with overlapping of the fragments and considerable callus formation. There was apparently some sclerosis of the ends of the fragments (Fig. 8, *A*).

Operation.—Oct. 24, manipulation was done, together with refracture; calipers were applied with a Thomas splint, fixed to an overhead frame, and 25 pounds (11.3 kg.) traction was applied.

The roentgen-ray, Nov. 19 (Fig. 8, *B*), presented evidence of complete correction of the overriding, and actual separation of the ends of the fragments. The weight was then decreased to 15 pounds (6.8 kg.) and measurements showed that the legs were of the same length. Dec. 13, 1921, the roentgen-ray revealed good alinement, and end-to-end apposition of the fragments (Fig. 9). Jan. 18 1922, the patient was allowed to get up, making use of a walking caliper splint in order to stimulate union. A displacement of the fragments occurred, with

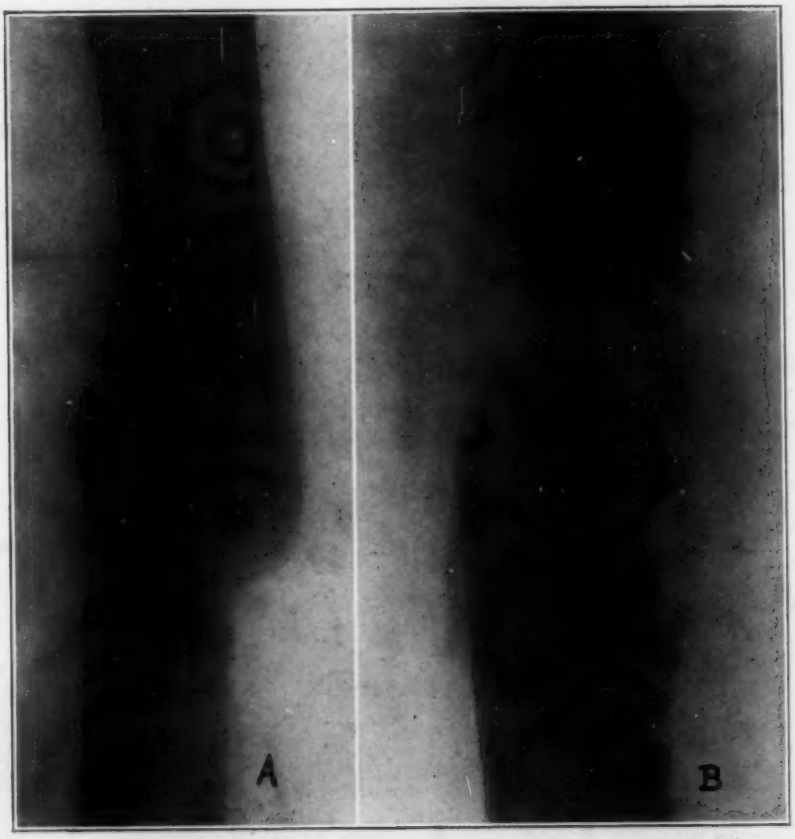

Fig. 8 (Case 3).—Appearance of fracture, *A*, on admission (October 19), four months after injury, showing union with overlapping of the fragments; *B*, after manipulation and caliper traction (November 19), showing correction of overlapping and separation of the fragments.

some overriding. After a period of several months there was still definite evidence of nonunion.

August 26, the patient was readmitted to the hospital for operation. The fragments were exposed through a lateral incision; they were found to be sclerotic and the medullary canals closed by bone. The sclerotic ends were removed, and the fragments were fixed with a beef bone plate and four beef bone screws. The wound was closed with catgut and silkworm gut, and the

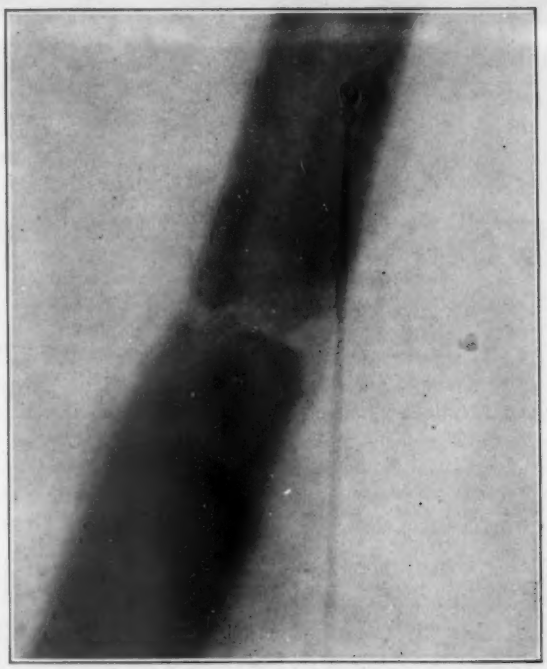

Fig. 9 (Case 3).—Excellent alinement and end to end apposition of fragments.

Fig. 10 (Case 3).—(Feb. 3, 1923) six months after the application of beef bone plate and screws.

limb was immobilized on a Thomas splint. Convalescence was uneventful, and the wound healed by first intention.

November 15, the patient was up and bearing weight, with the limb supported by a Thomas caliper splint. November 16, he was discharged from the hospital.

Feb. 2, 1923, the patient was walking without support to the limb. There was an inch (2.5 cm.) of shortening, good alinement and solid union. The knee joint was limited in flexion to 60 degrees. The roentgen-ray examination, Feb. 3 (Fig. 10), showed excellent alinement of the fragments with union. August 15, the patient was carrying on his work and his only complaint was that he could not flex the knee beyond a right angle.

TREATMENT OF UNUNITED FRACTURES OF THE FEMUR

The condition commonly found in delayed union of the femur is an unreduced fracture, incompletely fixed in deformity by adaptive changes in the soft parts, and a varying amount of callus. In the majority of cases, this callus has reached a stage of comparative inactivity. The treatment indicated, therefore, is reduction of the fracture and stimulation of osteogenesis. These can be accomplished by manipulation and by caliper traction. Manipulation serves a two fold purpose; it disengages the fragments from a mass of fibrous tissue and callus, and, by so doing, it stimulates the callus to renewed activity. Traction by calipers will readily overcome the shortening, and, if there is lateral displacement, it can be corrected by the use of the screw pressure pads.

Once the fragments are brought into accurate alinement, union can be hastened by percussing the callus with a rubber mallet and by placing constricting rubber bands above and below the site of fracture. This method was described by Hugh Owen Thomas, and was called by him, "percussion and damming."

When there is evidence of union, consolidation of the callus can often be aided by the use of the Thomas walking caliper splint, the principle of treatment being a traumatic irritation of callus by partial weight bearing.

In nonunion of the femur, I believe that manipulation and caliper traction have a useful place, especially in those cases showing marked overlapping of the fragments. The method might well be described as the preliminary phase of the treatment, its object being restoration of length before open operation.

In my experience, the great difficulty in operations for nonunion in overlapping fracture of the femur is to secure end-to-end apposition of the fragments without considerable sacrifice of bone. This results in permanent shortening. If the length is gained by traction as a preliminary to operation, removal of the sclerotic bone and apposing of the freshened ends of the fragments becomes a comparatively simple procedure.

The following cases of delayed and ununited fractures of the femur illustrate the foregoing method of treatment.

CASE 4.—*History.*—S. S., a laborer, aged 23, was admitted to the University Hospital, Aug. 20, 1921, complaining chiefly of an old fracture of the right femur. The patient had been injured in an automobile accident, May 2, when he sustained a fracture of the right femur. He was taken immediately to a hospital, where the limb was immobilized in a plaster of Paris cast. Nine weeks later the plaster was removed, and patient was allowed to bear weight on the affected extremity without support. He complained at once of pain on weight bearing, and, on entrance, his chief symptoms were of pain and inability to bear weight on the affected leg.

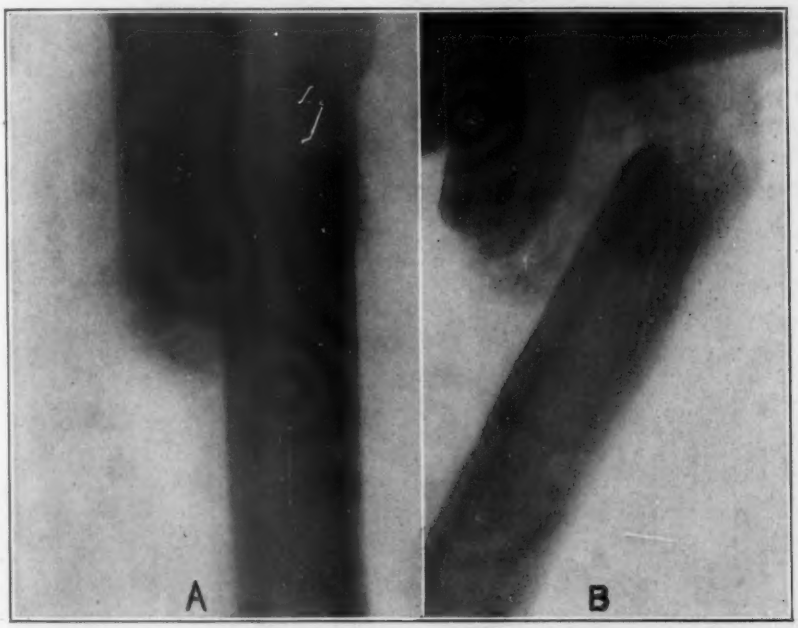

Fig. 11 (Case 4).—Appearance of fracture: *A*, on admission (Aug. 22, 1921), showing overlapping of the fragments and considerable callus; *B*, lateral view showing angulation of the fragments.

Physical Examination.—The right thigh showed marked wasting of the thigh muscles with posterior sagging and lateral bowing at the middle third of the femur. There was motion between the fragments, accompanied by pain, and the knee joint was rigid and somewhat swollen. One and one-half inches (3.8 cm.) shortening was present.

August 22, the roentgen ray showed a transverse fracture of the femur, with overlapping and posterior displacement of the upper end of the lower fragment (Fig. 11, *A* and *B*). The Wassermann reaction on the blood was negative, as well as the urine examination.

Operation.—August 22, manipulation was done, together with thorough freeing of the fragments, and calipers were applied to the condyles of the femur.

A Thomas splint was applied and fixed to the overhead frame. The initial weight of 15 pounds (6.8 kg.) was increased to thirty pounds (13.6 kg.) in the course of one week.

September 9, the roentgen ray showed that there was over-extension of the leg with some lateral displacement (Fig. 12, *A*). Pressure pads were applied to correct this displacement. Sept. 15, 1921, the roentgen ray revealed almost complete correction of the lateral displacement (Fig. 12, *B*). The calipers were removed Oct. 2, and the limb was immobilized with adhesive tape traction and coaptation splints.

Dec. 22, 1921, the roentgen ray showed union with good alinement (Fig. 13). The patient was allowed to use a walking caliper splint, but a few days later

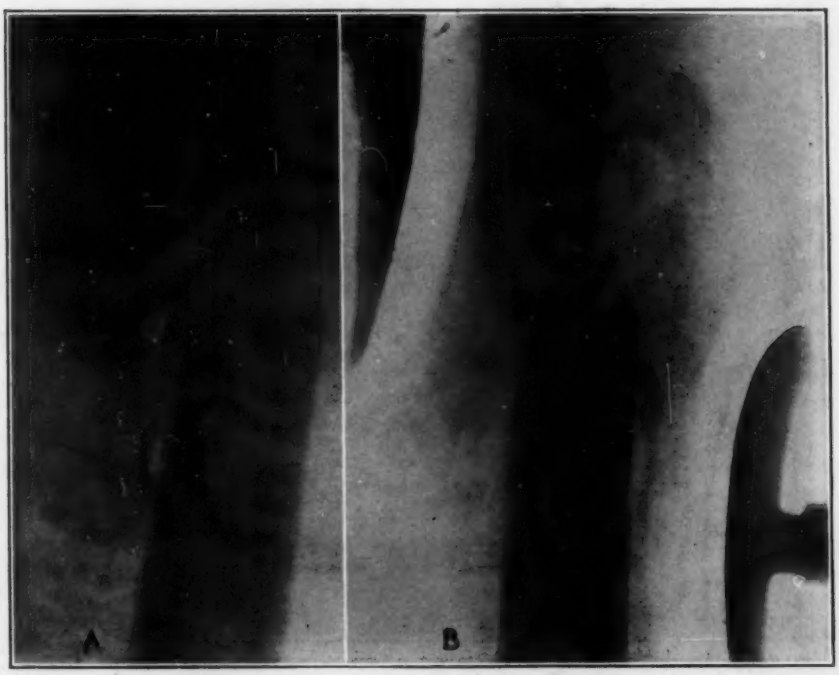

Fig. 12 (Case 4).—Appearance of fracture: *A*, position of the fragments after manipulation and caliper traction (Sept. 9, 1921); *B*, correction of lateral displacement by pressure pads.

he complained of pain in the lumbar region. The roentgen-ray examination revealed a kidney stone, and he was transferred to the general wards, where the stone was removed. This necessitated his remaining in bed for some weeks, and after that time he began to walk again on the caliper splint. The final result showed union with full length, although there was marked stiffness of the knee from the prolonged immobilization. The patient returned home, and no report of his condition has been received since.

Case 5.—*History.*—J. P., a laborer, aged 27, was admitted to the University Hospital, Aug. 10, 1921, complaining of inability to bear weight on the right leg because of a fracture of the femur. Ten months before his admission he

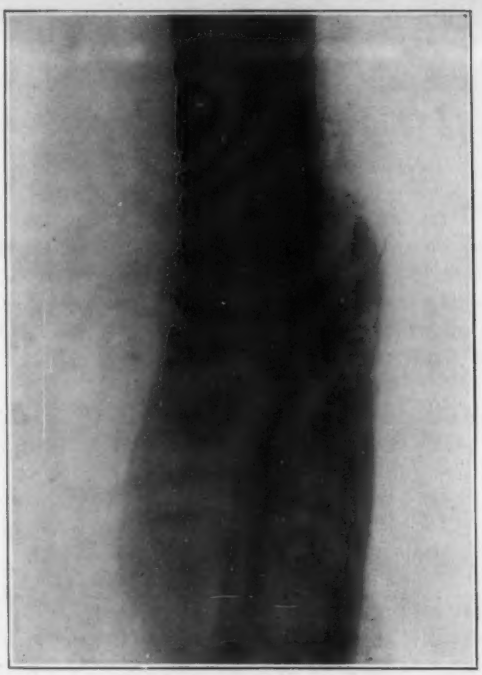

Fig. 13 (Case 4).—Final result (December 22), with union and good alinement.

Fig. 14 (Case 5).—Appearance of fracture: *A*, position of fragments on admission to the hospital (Aug. 15, 1921), ten months after receiving injury, showing the marked angulation; *B*, end result (March 10, 1922), after manipulation and caliper traction, showing bony union with excellent alinement and full length.

had been injured in an automobile accident, he sustaining, besides minor injuries, a fracture of the right femur. Traction and splints were applied for a period of eight weeks. A satisfactory position not having been obtained, he was operated on, and a bone graft was inserted. Again, there was failure to obtain union, and finally the patient was referred to the University Hospital for treatment.

Physical Examination.—The patient walked with a decided limp and complained of severe pain when bearing weight on the right lower extremity. There was considerable swelling of the right leg and foot, very marked stiffening of the right knee joint, and an inch (2.5 cm.) of shortening. The blood Wassermann reaction and the urine examinations were negative.

August 15, the roentgen-ray examination revealed an oblique fracture of the upper third of the femur, with lateral bowing and wide abduction of the upper fragment (Fig. 14, *A*).

Operation.—August 17, manipulation was done, together with thorough freeing of the fragments. Calipers were applied to the condyles of the femur, and a Thomas splint was fixed to an overhead frame with fifteen pounds (6.8 kg.) traction. A pressure pad was used to correct the abduction of the upper fragment.

By November 2, there was good alinement, with full length of the limb. The patient was allowed to use a walking caliper splint. Union was stimulated by massage, and percussion with a rubber mallet.

March 10, 1922, the examination showed excellent alinement, with union and full length. Roentgenograms taken on this date showed perfect alinement and bony union (Fig. 14, *B*).

Case 6.—*History.*—M. F., a laborer, aged 30, was admitted to the University Hospital March 12, 1921, complaining of inability to walk because of a fracture of the femur. Dec. 5, 1920, the patient had sustained a fracture of the left femur in an automobile accident. On admission to a hospital, adhesive traction was applied with weight and pulley extension. After four weeks, the adhesive was removed and the limb was immobilized in plaster of Paris for a period of six weeks. The plaster was removed then, and the patient was allowed to use crutches, although he was unable to bear weight on the affected extremity. Several months later, he was admitted for treatment of an ununited fracture of the femur.

Physical Examination.—The general examination was negative; the local examination showed a moderate amount of swelling of the left thigh, with an ununited fracture of the middle third of the femur. There was distinct angulation with some lateral bowing, free movement between the fragments and 2 inches (5 cm.) of shortening. The roentgen-ray examination, March 14, 1921, revealed an ununited fracture of the left femur, with rather marked angulation and overriding of the fragments. There appeared to be some rounding off of the end of the fragments (Fig. 15, *A*).

Operation.—March 14, under gas and oxygen anesthesia, manipulation was done in order to free the fragments thoroughly, and calipers were applied to the condyles of the femur. A Thomas splint was applied, and suspended to an overhead frame with 20 pounds (9 kg.) traction.

The roentgen ray, March 25, eight days after the application of calipers, showed a complete correction of overriding, with one-fourth inch (6 mm.) separation of the fragments (Fig. 15, B). The rounding off of the ends of the fragments, with some walling off of the medullary canals, seemed an indication for operation in order to secure union.

Operation.—March 27, the fragments were exposed; they were found surrounded by fibrous tissue, and there was definite sclerosis of the ends of the fragments. After the sclerotic bone was removed the ends of the fragments were apposed, and fixed with a Lane plate.

March 30, the roentgen ray showed excellent alinement of the fragments (Fig. 16). Convalescence was entirely uneventful; on April 8 the stitches were removed, and the wound healed by first intention. By June 23 there was solid union, and the patient was allowed to us a walking caliper splint. By

Fig. 15 (Case 6).—Appearance of fracture: *A*, on admission (March 14, 1921), showing ununited fracture, with angulation and overlapping of the fragments; *B*, after manipulation and caliper traction (March 25). The correction of overriding and separation of the ends of the fragments may be noted.

September 29 the patient had been walking with the caliper splint for a period of three months. The splint was removed and the patient admitted to the hospital, where, under gas and oxygen anesthesia, the plate was removed. At the operation, solid bony union was revealed. The wound healed by first intention, the stitches were removed, and the patient was discharged from the hospital ten days later.

November 22, when the patient returned for observation, examination revealed solid union, with less than one-half inch (1.27 cm.) of shortening. He walked without any limp, and could flex the knee to a right angle. The roentgen ray showed union with perfect alinement (Fig. 17).

CASE 7.—*History.*—A school girl, aged 17, was admitted to University Hospital Feb. 10, 1921, complaining chiefly of pain in the left hip joint. In July,

Figure 16

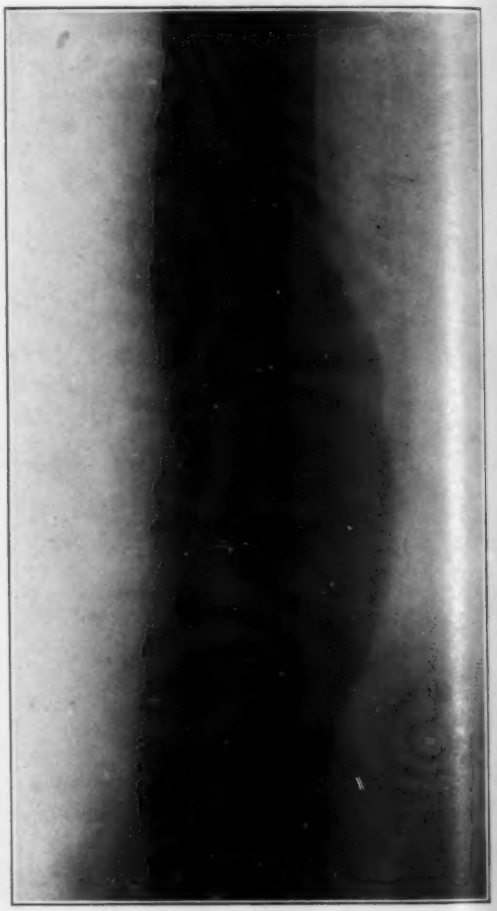

Figure 17

Fig. 16 (Case 6).—Appearance of bone after operation and application of the Lane bone plate (March 30).

Fig. 17 (Case 6).—Appearance of bone, after plate has been removed (November 22), showing union and good alinement.

1915, the patient had fallen from a roof and sustained a fracture of the left hip. The immediate treatment consisted of manipulation and fixation in a plaster of Paris cast. After six weeks, the plaster had been removed, and she was allowed to go about on crutches. A few weeks later she discarded the crutches

and attempted to bear full weight on the affected extremity. There had been gradual improvement over a period of months, but she was greatly handicapped by shortening, deformity and limitation of motion of the left hip joint. She managed, however, to carry on her school work for several years until finally, on Feb. 8, 1921, she slipped and fell directly on the left hip. She was immediately disabled because of the severe pain, and was admitted to the hospital for treatment.

Physical Examination.—The local examination showed an adduction and flexion deformity of the left hip. There was a shortening of 3 inches (7.6 cm.) or

Fig. 18 (Case 7).—Fracture of the neck of the femur with absorption of the head and neck, and upward displacement of the trochanter, on admission (Feb. 14, 1921) six years after the injury.

more, but this could not be measured accurately because of the deformity. The motion of the hip joint was limited in all directions, and there was severe pain and muscle spasm. The Wassermann reaction on the blood and the urine examinations were negative. The roentgen ray examination, Feb. 14, 1921, revealed a fracture of the neck of the femur with almost complete loss of the head and neck. The trochanter was displaced upwards and lay well above the acetabulum (Fig. 18).

February 14, a Thomas splint with adhesive traction was applied, and counter-extension was obtained by elevating the foot of the bed and fixing the lower end of the splint.

Measurements made March 11, failed to show any gain in the length of the limb. Calipers were than applied, and the Thomas splint was suspended to the overhead frame in the usual manner, using twenty-five pounds (11.3 kg.) weight. The roentgen ray, March 19, showed the trochanter pulled down to the level of the acetabulum. The actual increase in the length of the leg was 1½ inches (Fig. 19).

Fig. 19 (Case 7).—Trochanter on the level with the acetabulum, after caliper traction (March 19).

Operation.—March 21, 1921: The Smith-Peterson incision was employed in order to expose the hip joint. The capsule was incised, and the head of the femur, which was markedly atrophic, was removed. The cartilage of the acetabulum was removed with a gouge, while the trochanter was freed from muscle insertions subperiosteally, exposing cancellous bone at its upper surface. A graft was removed from the outer upper portion of the trochanter and, after the remaining portion was placed within the acetabulum, the graft was made to lie against the ilium just above the acetabulum. The wound was closed with catgus and silkworm gut sutures. The limb was fixed in about 20 degrees of abduction and 20 degrees of flexion, and a plaster of Paris cast applied.

March 25, the wound was septic, and drained a considerable amount of pus. Counter drainage was established, and the wound finally healed on Aug. 21, 1921.

Aug. 21, 1921, the roentgen ray showed the trochanter lying well within the acetabulum, and the presence of ankylosis (Fig. 20). The limb was fixed in a short plaster of Paris spica, and the patient was allowed to make use of crutches. September 15, she was discharged from the hospital.

Fig. 20 (Case 7).—Appearance of bone (August 21), after operation for arthrodesis of the hip showing solid ankyloses. Union of trochanteric graft may be noted.

Feb. 22, 1922, approximately a year after the operation, the patient returned for examination. The spica had been removed two months before, and the patient was walking with only a moderate limp. She walked fairly well, and there was no complaint of pain. The examination showed that there was about 25 degrees of flexion of the hip, with about 15 degrees of abduction. There

was a solid ankylosis of the joint. The patient stated that the limb was getting stronger, and that, to her, it seemed to be as long as the uninjured leg. This can be accounted for by the abduction present on the affected side.

WEIGHT BEARING IN THE TREATMENT OF FRACTURES OF THE FEMUR

The decision as to when a patient with a fracture of the femur is to bear weight on the affected extremity should not be determined by

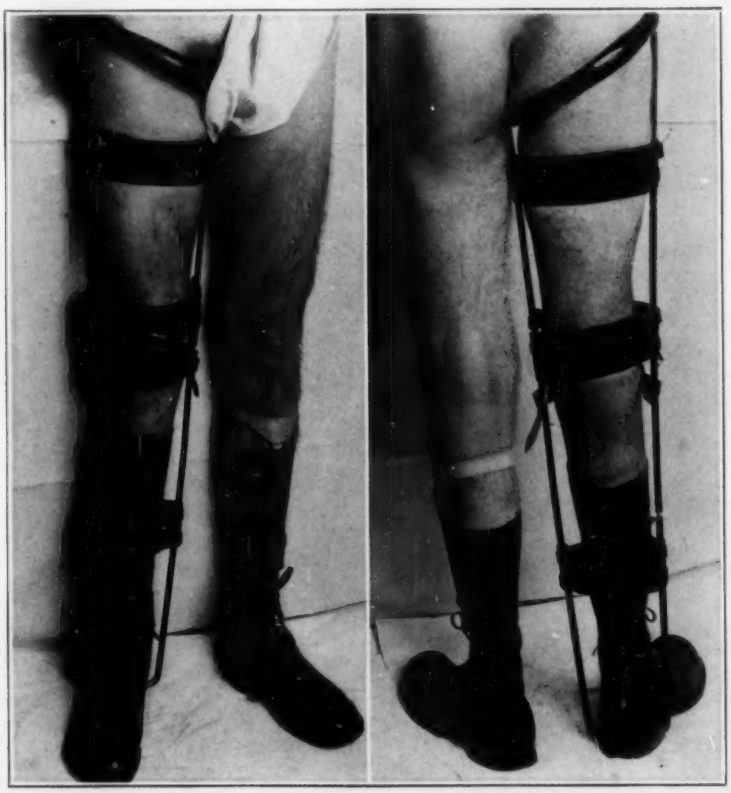

Fig. 21.—Thomas walking caliper splint; left, anterior view; right, posterior view.

the number of weeks which have elapsed since the injury was received, but rather by the findings elicited by examination of the fracture and a study of the roentgenograms. The absence of tenderness over the fracture and the evidence of reduction with a callus of uniform density surrounding the fragments, as shown by the roentgenograms, are indications which warrant a trial of the ambulatory treatment. It is true, however, that, even when solid union apparently exists, weight bearing may cause bending of the callus, which gradually increases until a real

malunion is present. As a preventive measure, therefore, it is sound practice to protect the fracture by some form of appliance during the period when the callus is undergoing consolidation.

The best protective appliance with which I am familiar is the Thomas walking caliper splint (Fig. 21). It is simple in design and very efficient. The leather ring is fitted very accurately to the tuberosity of the ischium, while the lower ends of the lateral unright are bent at right angles and inserted into the heel of the boot. It is essential that the lateral bars be of the proper length, so that when the ischial tuberosity is resting on the ring, the foot shall not reach the heel of the boot. With the patient in the upright position, the weight is transmitted from the tuberosity of the ischium directly through the lateral uprights to the heel of the shoe, and undue strain on the site of fracture is avoided.

The splint should be worn until there is no tenderness over the callus and the roentgenograms show complete consolidation. It should then be removed for a short interval and full weight bearing allowed, the splint being finally discarded when, after observation, there is no evidence of deformity.

CONCLUSIONS

1. Excellent results in the treatment of fractures of the shaft of the femur are directly dependent on the efficiency of traction and counter-traction.

2. The most efficient traction and counter-traction are obtained by the use of calipers and the Thomas splint, after the method of Pearson.

3. Malunited fractures of the femur, even those of several months duration showing tenderness over the callus, can be refractured by manipulation, and union with full length and accurate alinement can be secured by caliper traction on a Thomas splint.

4. Manipulation and caliper traction can frequently be used to correct deformity and to promote union in cases of delayed union of the femur. In nonunion, it is a valuable adjunct as a preliminary to gain length before operative treatment.

5. A protective weight bearing appliance should be accepted as standard in the treatment of all fractures of the shaft of the femur in adults. The Thomas walking caliper splint is the practical solution of the problem.

SHORTENING AND COMPENSATORY OVERGROWTH FOLLOWING FRACTURES OF THE FEMUR IN CHILDREN

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Two years ago, Kellogg Speed [1] reported sixty-seven cases of fracture of the femur in children in which he evaluated the relative results of treatment by cast, extension with the leg supported on the bed, and continuous extension with the leg elevated and supported by an overhead frame. His results decidedly favored the method last named. Burdick and Siris [2] also presented a paper advocating overhead continuous traction in treatment of fractures of the femur in children.

The material presented in this paper is the result of the study of seventy-five children with fractured femur who were treated on the joint service of Dr. George G. Davis and myself at the Cook County

TABLE 1.—*Age Incidence in Fracture of Femur*

Age Years	Number of Patients	Age Years	Number of Patients
1	8	7	9
2	6	8	7
3	11	9	5
4	7	10	4
5	3	11	8
6	7		

Hospital between Jan. 1, 1922, and June 1, 1923. The ages of the children varied from 1 year to 11 years. Table 1 shows the occurrence of the fractures according to ages.

All but three of these patients came to the hospital within four days after injury, and sixty-four came within twenty-four hours after injury Direct injury, particularly by an automobile, was responsible for the fracture in thirty-four cases; whereas, in forty-one cases fracture resulted from falls or indirect injury. Twenty-two of the patients had other injuries, but only two of the seventy-five patients had compound fractures. There were no fractures of the neck of the femur, nor were there any supracondylar fractures of the lower end of the femur. The upper third of the femur was fractured in sixteen cases; the middle

1. Speed, Kellogg: Surg., Gynec. & Obst. **32**:527 (June) 1921.
2. Burdick, E. G., and Siris, J. E.: Ann. Surg. **77**:736 (June) 1923.

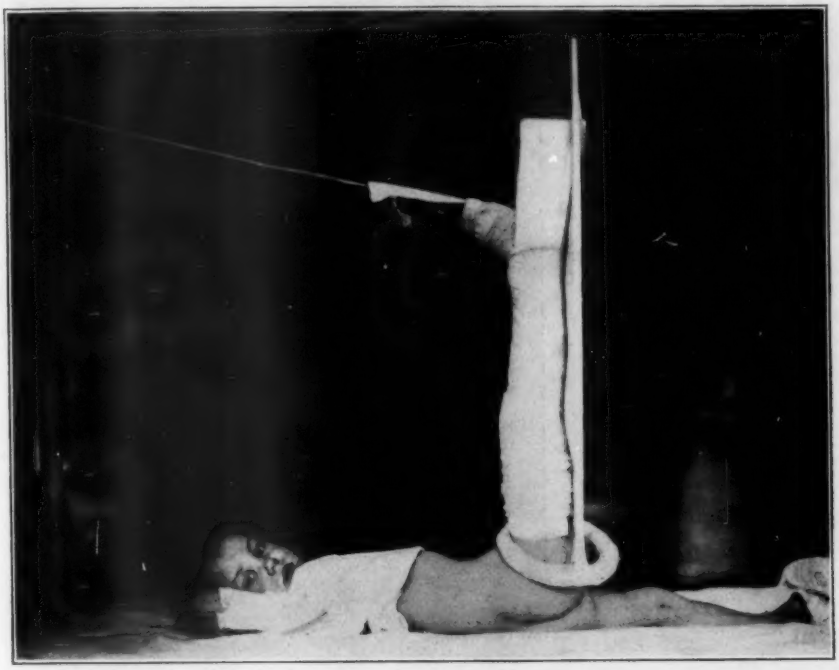

Fig. 1.—Small child in overhead extension for fracture of femur. Buck's extension pulls the buttocks on the affected side off the bed.

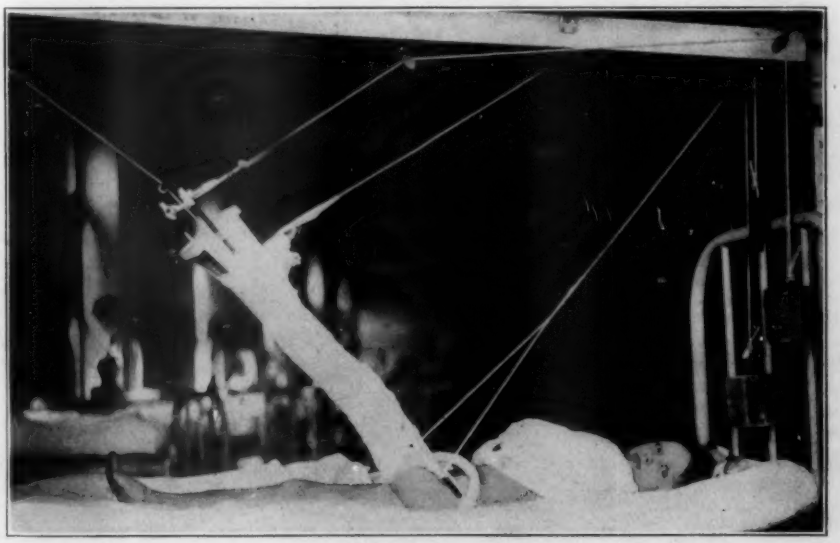

Fig. 2.—Large child with leg in flexion abduction and external rotation. The rope of Buck's extension takes a turn around the end of the Thomas splint, so that the traction is through the splint and is more uniformly distributed to the adhesive on the leg.

Fig. 3.—Thomas caliper walking splint.

Fig. 4 (Case 1, G. F., aged 8 years).—*A*, femur in extension two days after injury; 1 inch shortening; no end-to-end apposition of fragments. *B*, appearance three weeks after injury, with callus formation, seven-eighths inch shortening and good alinement. *C*, appearance three months after injury. The walking caliper has been removed, and there is one-half inch shortening. *D*, thirteen and one-half months after injury; no shortening and no deformity.

third in forty-five, and the lower third in fourteen. Many of the fractures from direct injury were transverse, with marked displacement of the fractured ends, but many types of oblique and spiral fractures were observed.

MANAGEMENT

The principles underlying the treatment of the cases were uniform. As soon as the patient had recovered from the shock of his injury and had been bathed, Buck's adhesive extension was applied to the injured limb, running from the level of the fracture to the ankle; care being taken to protect the condyles of the femur, the head of the fibula and

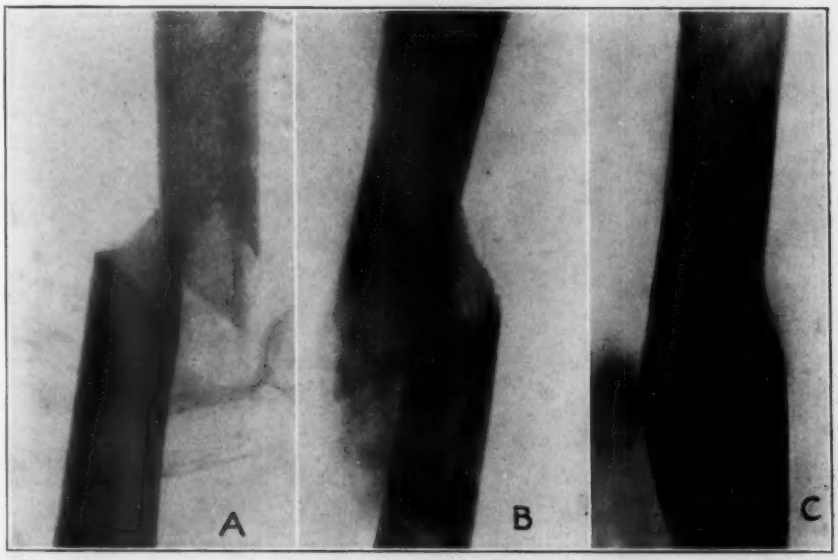

Fig. 5 (Case 2, A. G., aged 8 years).—*A*, transverse fracture of the upper third, eight days after injury. There is little shortening. *B*, appearance nine weeks after injury. The femur is in a walking caliper. There is some overriding, with one-half inch shortening. *C*, appearance five months after injury. There is no shortening and no deformity.

the malleoli of the tibia and fibula from pressure. The longitudinal adhesive strips were securely anchored by spiral adhesive strips so that the leg below the fracture was virtually encased in adhesive. A short complete circle Thomas splint covered with flannelet to support the leg was slipped over the leg and attached to an overhead frame, as shown in Figures 1 and 2. It will be noticed that the rope from the Buck extension takes a turn around the end of the Thomas splint so that the traction obtained is through the splint and not on it (Fig. 2). The only use of the Thomas splint, therefore, was to support and pro-

tect the leg. It was not used at all in very young children. In poorly muscled children and usually in those under 8 years of age, the leg was placed at right angles to the body with enough traction to raise the buttocks off the bed on the affected side. This resulted in flexion, abduction and slight external rotation of the long fragment of the

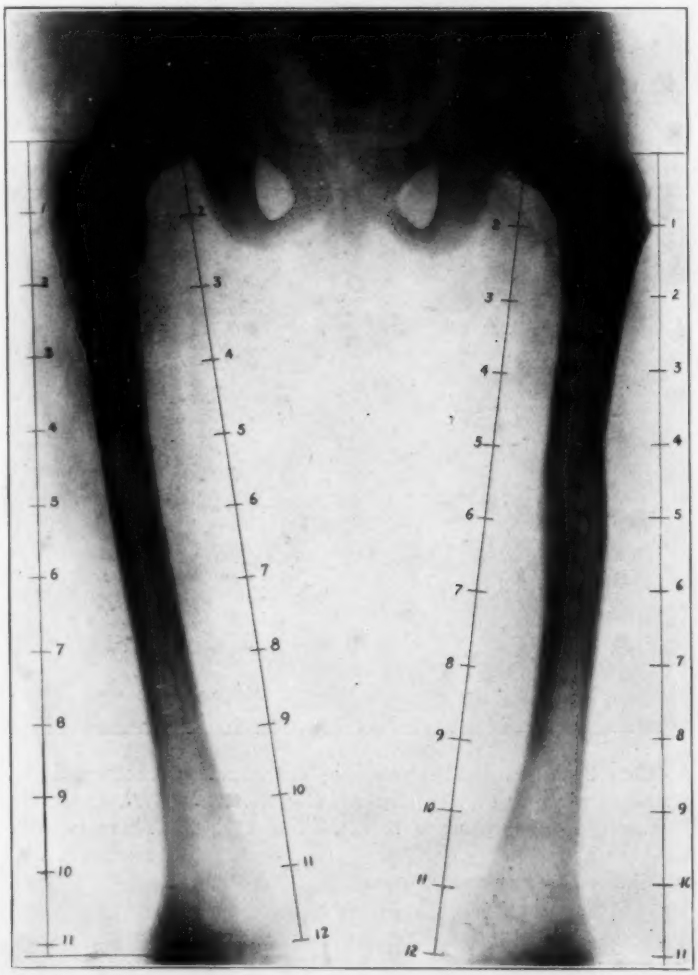

Fig. 6 (Case 2).—Appearance twenty months after injury. There is no shortening and practically no deformity.

femur, putting it in alinement with the shorter, less controllable fragment (Fig. 1). In well muscled children or in children from 8 to 11 years, the leg was not put at right angles to the body because the position was not comfortable and, of more importance, the weight of

the body, when the buttock on the affected side was raised by the traction overhead, did not produce enough countertraction to prevent muscle spasm, with consequent pain and deformity. Therefore, in these older children, the leg was lowered and overhead traction was used with the leg in flexion, external rotation and abduction, as shown in Figure 2. Foot drop was prevented when necessary by slight traction on the toes (Figs. 1 and 2). No attempt was made to reduce the fractures by

Fig. 7 (Case 3, M. N., aged 9 years).—*A*, fracture of the upper third of the femur, five weeks after injury. There is marked overriding and 1 inch shortening, but no end-to-end apposition of fragments. *B*, appearance six and one-half months after injury. There is one-half inch shortening and good function.

manipulation under anesthesia, but roentgenograms were taken as soon as the leg was placed in the apparatus, in order to see that alinement of the fractured bones was as good as possible and that sufficient traction was being used to correct marked overriding. As will be seen in the roentgenograms, many of the fractures had no end-to-end apposition whatever. It must be stated that end-to-end apposition is desirable,

and that, when possible, adjustment under a fluoroscope should have been attempted; but such treatment was out of the question in this series because of pressure on the roentgen-ray department from all over the hospital. Frequent readjustment and correction of the extension apparatus was carried out, and this is most important during the first ten days, before a hard callus has developed at the site of fracture.

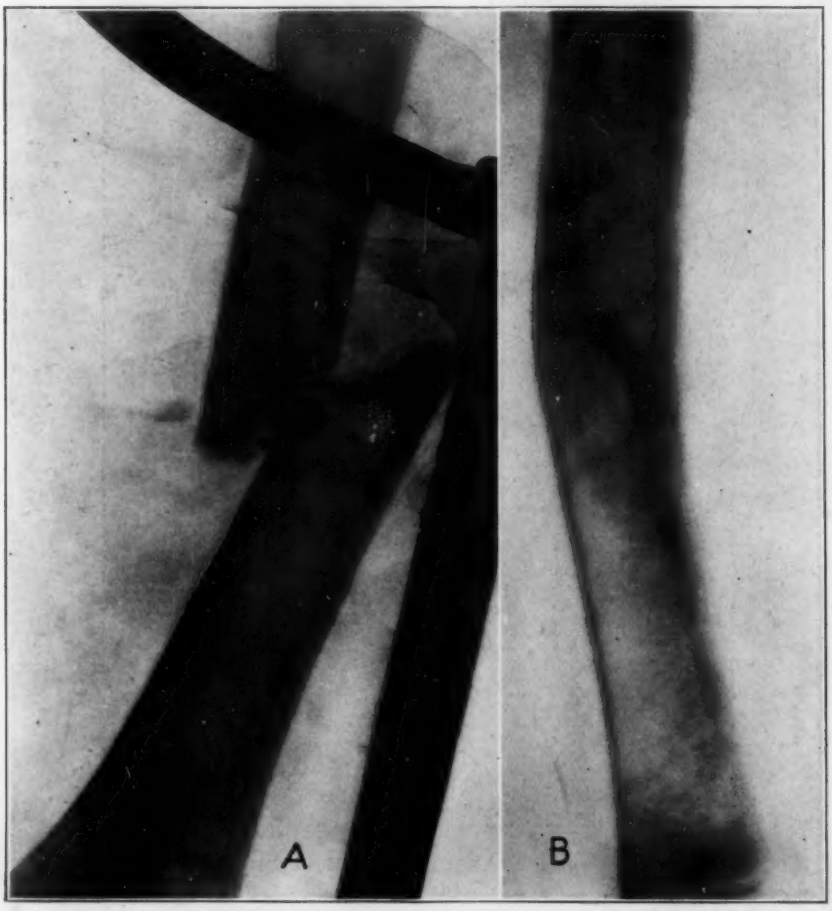

Fig. 8 (Case 4, E. F., aged 6 years). *A*, fracture of the femur at the junction of the middle and lower thirds; posterior angulation of the lower fragment. There was one-fourth inch shortening at the end of six weeks. *B*, appearance seven months after injury. There is no shortening and no deformity.

After an average of six weeks in overhead extension, the leg was removed from the Thomas splint and Buck's extension, and after a few days of massage and motion in the knee joint, was put into a walking Thomas caliper splint, as shown in Figure 3. Thirteen patients

were put into a spika body and hip cast until the caliper was obtained. This walking Thomas caliper, having the ring firmly adjusted to the tuber ischii on the affected side and attached to the heel of the shoe, kept the leg in continued extension for an average of seven weeks more, and prevented bending of a soft callus with consequent deformity.

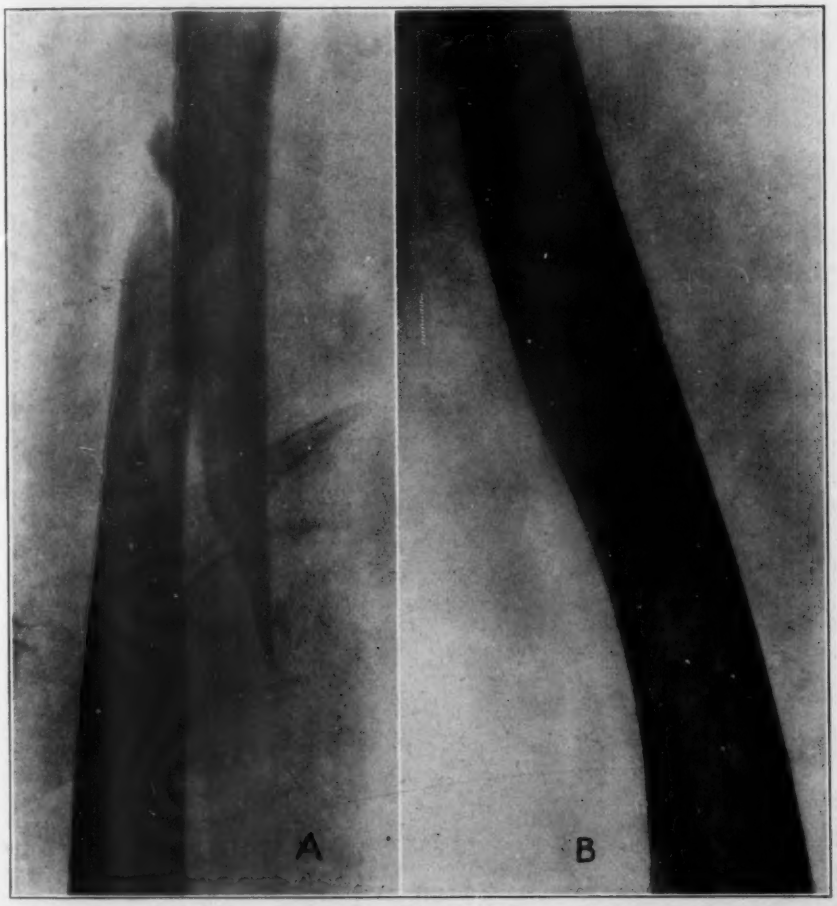

Fig. 9 (Case 5, L. P., aged 4 years).—*A*, appearance of femur, showing one-half inch shortening after six weeks of traction in overhead extension. *B*, appearance twelve months after injury; one-eighth inch shortening, no deformity and perfect function.

As soon as the leg was removed from the overhead extension, new roentgenograms were taken, and careful measurements of the injured and uninjured femurs were made. As the accuracy of the measurements may come in question, it may be said that the patient was placed on a hard table with all clothing off, with the anterior superior spines of the pelvis on the same level and with the heels equidistant from a

line running from the umbilicus through the symphysis pubis to the level of the internal malleoli of the tibia. Measurements were made by me in the majority of the instances, from the anterior superior spine to the tip of the internal malleolus. In many cases, measurements of the

Fig. 10 (Case 6, W. R., aged 4½ years).—*A*, oblique fracture of the lower third of the femur; after five weeks in overhead extension. There is three-eighths inch (9.5 mm.) shortening. *B*, appearance five and one-half months after injury. There is no shortening and no deformity.

femurs alone were made, to ascertain that the shortening present was really in the femurs. As these patients returned to the fracture follow-up clinic which I held every week, observations, measurements and roentgenograms were made repeatedly over a period varying from

two months to nearly two years after the time of injury. In all, seventy-one of these seventy-five patients were observed, the remaining four refusing to return to the follow-up clinic.

At the time of removal from the overhead extension, the shortening varied from 2 inches (5 cm.) in one patient to no shortening. Table 2

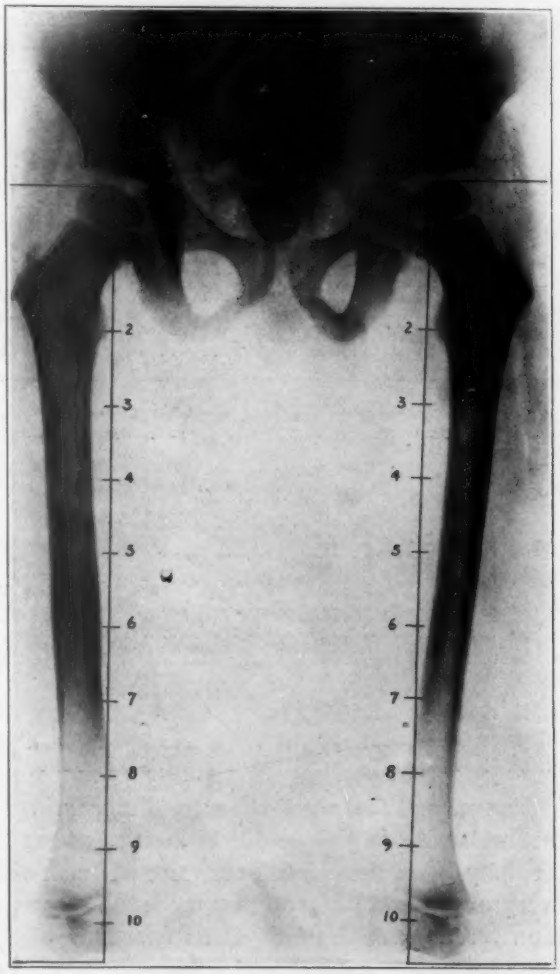

Fig. 11 (Case 6).—Appearance eleven months after fracture, showing equal length of femurs and lack of deformity.

shows the amount of shortening present at the time of removal from the overhead traction, which is an average of six weeks from the date of injury.

In thirty-seven of the patients, a shortening of one-half inch (1.3 cm.) or less was of little consequence and produced no deformity or

limp but a shortening of over one-half an inch (12.7 mm.) was not lightly regarded, and was often associated with a slight or pronounced limp. It was with especial interest and with some anxiety that these patients were followed, as the question of operative correction of the more marked instances of shortening obviously deserved consideration. As time went on, it became apparent that the injured and shortened legs

TABLE 2.—*Shortening Noted on Removal of Traction*

Shortening Inches	Number of Patients
None	9
⅛	2
⅞	11
⅜	10
⅝	14
⅝	3
⅝	10
1	9
1¼	2
2	1

TABLE 3.—*Return Toward Normal Length in Uncompleted Cases*

Shortening Inches	Time Months (Average)	Number of Patients
2 to 1	19	1
1¼ to ¾	5	2
1¼ to ½	7	5
¾ to ½	5	3
¾ to ¼	8	4
½ to ¼	4	6
⅜ to ¼	5	1
⅜ to ⅛	2	2

were becoming longer and that the limps were disappearing. This could not be due to stimulation of epiphyseal lines such as occurs in osteomyelitis near the epiphysis, as these fractures were not near the epiphyseal lines. The overgrowth must be compensatory and a response to the law of compensation for restoration of impaired function.

In Table 3 the return toward normal length in the uncompleted cases is shown. Most of the cases are the most recent ones, in which we have every reason to believe the shortening of the injured leg will eventually be overcome.

The most striking instance in Table 3 is the presence of 2 inches (5 cm.) shortening, which has been reduced to one inch (2.5 cm.) shortening in nineteen months.

In Table 4, forty-seven completed cases, the amount of shortening at the end of the period of overhead extension is given, and the average

length of time which elapsed before the injured femur attained the length of the normal uninjured femur.

No attempt will be made to explain the principles underlying the compensatory overgrowth of these shortened femurs. It has been observed before, and some reference is made to it in the literature. Truesdell [3] reported five cases in children in which lengthening of the affected femur was noticed in place of shortening that had been present at the time the patients left the hospital. The fractures did not involve

TABLE 4.—*Amount of Shortening and Time Elapsed Before Femur Attained Normal Length*

Shortening Inches	Number of Patients	Return to Normal (Mos. Av.)
1	4	15
¾	3	9
⅝	3	9
½	8	5
⅜	7	5
¼	11	3
⅛	2	2
No Shortening	9	

the epiphysis. Cole [4] speaks of compensatory overgrowth of shortened femurs following fracture in children. Burdick and Siris [2] report fifteen cases in which the fractured limb was normal or shorter than the opposite side and subsequently lengthened. Of 118 cases having shortening on discharge from the hospital, fifty-three became normal within a period of from one year to three years.

The fact that compensatory overgrowth of a shortened femur after the fracture may be expected in a growing child is of extreme importance in further limiting operative interference in these cases.

Another point of interest in treating these cases is that alinement of the fractured ends to prevent angulation, and extension to prevent overriding of the fragments are of greater importance than end-to-end apposition of the fragments. This is desirable, but union takes place without it, provided marked overriding is prevented. The late roentgen-ray study of fractures in which no end-to-end apposition was obtained shows a restitution of the shaft practically to normal (Figs. 6 and 11).

25 East Washington Street.

3. Truesdell, E. O.: Ann. Surg. **74**:498 (Oct.) 1921.

4. Cole, Warren H.: Results of Treatment of Fractured Femurs, Arch. Surg. **5**:702 (Nov.) 1922.

TWENTY-FOURTH REPORT OF PROGRESS IN ORTHOPEDIC SURGERY *

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CONGENITAL CONDITIONS

Klippel-Feil Syndrome. — The Klippel-Feil syndrome has three essential features: (1) the extreme shortening of the neck, the head appearing to be sunken between the shoulders; (2) limitation of motion of the head, and (3) low implantation of the hair, the scalp extending downward to the upper part of the back. There are usually other associated deformities, such as scoliosis, round back, kyphosis, spina bifida, etc. Smeesters [1] has found fifteen cases reported in the literature and adds two more. It is obvious clinically that a malformation of the cervical spine exists. The anatomic explanation is found in a congenital fusion and lack of individualization of the cervical vertebrae, usually associated with a true spina bifida of this region.

Congenital Elevation of the Scapula.—Delchef [2] reviews all the known facts in reference to congenital elevation of the scapula, commonly known as Sprengel's deformity, although the condition had been described by several different writers at least ten years before Sprengel's first article on the subject. From embryologic studies he concludes that the condition must be considered as the expression of a disturbance of embryonic segmentation productive of malformations, varying in number and intensity, of the axial skeleton as well as of the scapular muscles. The elevation results from the arrest provoked by these disturbances of the normal descent of the scapula from the cervical to the dorsal region. From this standpoint, the condition is not to be considered as an entity,

* This Report of Progress is based on a review of 387 articles selected from 640 titles dealing with orthopedic surgery, appearing in medical literature between December 22, 1923, and April 26, 1924. Only those papers which seem to represent progress have been selected for note and comment.

1. Smeesters: Arch. Franco-Belges de Chir. **26**:1067 (Nov.) 1923.
2. Delchef: Revue d'orthopédie, Nov., 1923, p. 623.

but rather as a symptom, together with other accompanying malformations of this disturbance in embryonic development. The supernumerary bones found in many of the cases are not the cause of the deformity, but are rather an accidental complication. The actual etiology remains as obscure as that of other congenital malformations. The author agrees that operative treatment offers the only hope of amelioration. He follows the usual procedures of resection of the prominent upper angle; removal of any osseous bridges, sectioning all muscles and bands that resist the lowering of the scapula, and fixing it in the best possible position with wire or tendon or fascial bands by anchoring its superior (nota bene) mesial angle to the spinous processes and intraspinous ligaments.

[ED. NOTE.—None of the editors has ever seen a complete anatomic correction of the deformity from even a very extensive operation in a well marked case. They have often seen a very great improvement in appearance, but perhaps a word of caution as to a prognosis of cure may not be amiss. Certain points in the operative technic we believe are important: (1) a complete mobilization of the scapula in order to allow it to be brought down as far as possible; (2) partial or total removal of the upper angle; (3) any anchorage should ultimately allow considerable play in the scapula; (4) the shoulder should not be narrowed by fastening the scapula too near the median line, and (5) the final result will be most favorable when sufficient mobility of the scapula remains, to allow for the very important subsequent development of the chest and shoulder girdle by appropriate exercises.]

Congenital Dislocation of the Hip.—Soutter and Lovett [3] have made a very careful and valuable study of the end-results of 355 attempts at manipulative reduction of congenital dislocation of the hip at the Boston Children's Hospital. Eleven of these 355 attempts failed to reduce the dislocation after the amount of time and force considered wise had been expended. Thirty-five per cent. of the hips manipulated demanded a secondary reduction. In the supposedly more difficult cases, especially in those in which the patients were over 7 years of age, the machine devised by Dr. Bradford was employed. The authors believe that this is the method of choice in all patients over 7 years, and perhaps it has a wider range of usefulness than in these more difficult cases. It is certainly suggestive that in the cases (35 per cent.) requiring secondary reduction, there was a much smaller percentage (7 per cent.) of subsequent deformation of the head in those cases reduced by the machine than in those cases in which a required secondary operation was accomplished manually. Among these, 33 per cent. showed subse-

3. Souter, R., and Lovett, R. W.: Congenital Dislocation of Hip, J. A. M. A. **82**:171 (Jan. 19) 1924.

quent changes. This is a most important observation, for these later changes of growth are undoubtedly responsible for easy fatigue and actual pain and disability, which occur later in life in a fairly large percentage of successful reductions. Soutter and Lovett conclude that with adequate operation (bloodless) and after-care, from 80 to 90 per cent. of all congenital dislocations of the hips encountered before the seventh year ought to yield satisfactory results as to reposition and function. There were 71 per cent. of successes of this sort in all the cases they reviewed; forty-two cases could not be traced, and these they included with their failures, although many of them are believed to be successes; 83.8 per cent. of the cases in which they were able to make personal examinations were successful in both reposition and function.

Spontaneous Recovery of Congenital Dislocation of the Hip.—Slomann [4] has been able to find only twelve cases in literature of the spontaneous recovery of congenital dislocation of the hip. He adds two more cases, and although the histories are not complete, he is convinced that the shrinking of the capsule from some unknown exciting cause was responsible.

Club Foot.—Geist [5] is of the opinion that in a fair percentage of "corrected" cases of talipes equino varus, a toeing-in gait persists. Braces do not correct this, and Geist advises a transverse subperiosteal osteotomy of the tibia, with a subsequent rotation of the foot outward. This is the reverse of the procedure that Hoke has called a "tibial turning," and Geist finds it satisfactory and sufficient in simple cases.

Dunn,[6] like all the other orthopedic surgeons, is impressed with the frequency of the occurrence of congenital equino varus and also with the frequency of relapse after treatment. His rules of therapy are the following: (1) The treatment should be begun during the first month, consisting of repeated manipulations and the continuous maintenance of fixation in the corrected position. In the older resistant cases, after the correction of the adduction and inversion, he advises lengthening of the Achilles' tendon. If full correction cannot otherwise be obtained, Dunn advises other surgical methods, such as resection of the midtarsal region of the foot.

[Ed. Note.—We wish to plead rather strongly for a thorough, skillful, patient trial of the method of repeated manipulation, with or without an anesthetic, by strong hands alone or by weak hands aided by a Thomas (or other) wrench. We recognize the fact that this procedure is more time-consuming, requires more careful supervision, more plaster technic, and more constant control of the patient, but we

4. Slomann, H. C.: J. Bone & Joint Surg., **6**:38-49 (Jan.) 1924.
5. Geist, E. S.: J. Bone & Joint Surg. **6**:50-52 (Jan.) 1924.
6. Dunn, Noughton: Brit. M. J. **2**:1216 (Dec. 22) 1923.

are convinced that the end-results in most of the feet in which growth is still taking place, is much more satisfactory than the end-results after any operative procedure, except possibly Ober's operation of careful anatomic dissection of restricting ligaments and their appropriate division in resistant cases in older children. Operation, unless admittedly over-radical, does not always prevent relapse in cases not carefully followed. The lengthening of the Achilles' tendon is a serious operation—serious, we mean, in its tendency to permanently weaken the important calf group. The elder Little, the great popularizer of the method of tenotomy, advised that it should not be done when there was any hope of stretching the tendon. There is nearly always hope of stretching the Achilles' tendon in club foot if the surgeon will be patient. Bone resections in growing feet, even if they temporarily and perhaps permanently allow a correction of the deformity, result in feet of unequal size, and the problem of the shoe fitting becomes a harrassing lifelong problem. The operative cases that come back to our children's and adult's orthopedic clinics, are a disappointment and a warning in too large a percentage of cases. Section of the Achilles' tendon is easily done, but not as easily undone. If it is necessary, the tendon should be lengthened and sutured, not cut subcutaneously. As to Geist's proposed tibial osteotomy, the opinion of the editors is that it would be justifiable and probably an advantageous procedure if there exists an actual torsion of the tibia, but not a wise procedure to be employed merely to correct the malposition of the foot.]

Tuberculosis.—MacKinnon [7] calls attention to the fact that adults with bone or joint lesions of tuberculosis are, in a high percentage of cases, possessed of pulmonary tuberculosis. The frequency of pulmonary involvement, as well as the danger of pulmonary disease, should be borne in mind in consideration of the type of treatment to be employed in the surgical handling of the bone and joint lesions. MacKinnon believes that the disease is a general disease. He has made a careful study of thirty cases of adult bone tuberculosis.

Schwartz [8] presents an argument for what he terms "reconstructive therapy" in bone tuberculosis. He believes that local treatment is most effective when the patient's resistance is fortified against general infection by hygienic agencies, especially by the use of heliotherapy. The treatment should be individual, not routine, and methods of immobilization should be used only when there is pain, swelling, and muscle spasm. In the stage of the disease in which acute symptoms are subsiding, active use of the body or of the affected parts should be gradually begun.

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7. MacKinnon, A. P.: Canad. M. A. J. **14**:124 (Feb.) 1924.
8. Schwartz, R. P.: J. Bone & Joint Surg. **6**:133 (Jan.) 1924.

Lavalle [9] claims that he has attained good results in twenty cases of tuberculosis of the knee by the use of bone graft bridges. Similar grafts are removed from the tibia with the periosteum intact. Holes are drilled in the lower end of the tibia and the upper end of the tibia; then the grafts are driven into these holes, leaving an end projecting. To these projecting ends, bone graft bridges are secured by catgut sutures. A bridge of this nature is placed on each side of the knee. Union is said to take place in one month, and at the end of several months the child is allowed to run and play without any other form of support. After six or seven months of use the swelling and tenderness about the joint will have disappeared, and then the bridge should be removed. Normal function will quickly return to the diseased knee after the removal of the bone graft bridges. An interesting observation made in this report is that the grafts unite solidly and hypertrophy with use and that they exert a specific curative influence on the disease.

[Ed. Note.—The editors suggest that if this principle is proved valuable, it would be advantageous to simplify the technic.]

Clavelin [10] has again called attention to the well known but often overlooked fact that tuberculosis of the spine may present atypical symptoms. Not always are there kyphosis, paralysis, and abscess formation to depend on in making a diagnosis. On the contrary, his series of case reports shows that these symptoms are often lacking, and that the pain is of a referred character, which is difficult to associate with the spinal disease process.

Vacchelli [11] reports on a study of the ways of exit of abscesses arising from Pott's disease. His material for study was taken from the cases of Pott's disease treated at the Rizzoli Institute during the last fifteen years, 2,000 in number, and from the specimens in the museum. Studies were made by roentgenograms after the injection of abscess cavities with opaque substances such as bismuth bicarbonate. The author arrives at a definite set of conclusions, which he says are subject to the reservation that abscesses arising in a given skeletal segment will not always follow the same course. He makes an interesting observation in that he believes that the migration of these abscesses is not due simply to the progression of the pus, but that it is due to true progression of the process favored or impeded by anatomic conditions. There are three factors of importance in determining the course of an abscess,—gravity, the movements of the organs, and the quality of the

9. Lavalle, C. R.: Revue d'orthopédie, Jan., 1924, p. 5.
10. Chavelin, Ch.: Rev. de chir. **61**:749, 1923.
11. Vacchelli: La Chir. deg. Org. d. Mov. **8**:1(Dec.) 1923.

abscess, this last factor being judged from the activity of the tuberculous granuloma forming the wall of the abscess. The abscess progresses toward those regions and through those tissues that offer the least resistance.

PARALYSIS: INFANTILE, OBSTETRICAL, SPASTIC

Poliomyelitis: Paralysis of the Trapezius.—Perthes [12] reports that in a case of complete paralysis of the trapezius he has successfully transplanted the levator anguli scapulae. The incision was made along the posterior edge of the levator anguli scapulae, curving along the spine of the scapula. The spine is exposed by dissecting off the trapezius attachment. In the upper angle of the scapula a row of holes is drilled horizontally and parallel to its edge. A small portion of the angle is removed with the insertion of the levator anguli scapulae. With the arm held in abduction, this piece of bone with its muscular insertion is wired to the spine of the scapula, from which the periosteum has been scraped. The trapezius insertion is resutured over this new attachment and the arm placed on a right angle splint for four weeks. Perthes states that the functional result was excellent; the patient was able to do full work as a farmhand.

Transplantation of the Tensor Fasciae Femoris in Paralysis of Quadriceps.—Dunn and Stuart [13] report two cases of transplantation of the tensor fascia femoris to replace a paralyzed quadriceps femoris. They have been pleased with the results. One of the patients has recovered the power of almost complete extension.

Stern [14] has employed a procedure which he calls "patellapexy" in eight cases of paralysis of both quadriceps and hamstrings, to avoid the use of cumbersome braces. He secures an arthrodesis between the patella and the lower end of the femur. From 5 to 10 degrees of motion remain, which he considers an advantage in both sitting and walking.

Claw Foot.—Stuart [15] considers the principle of the Steindler operation sound for many cases of claw foot, and emphasizes the importance of not dividing the Achilles' tendon except as an absolute necessity. When the second metatarsal head cannot be replaced and the toes are in extreme dorsiflexion, he resects the mediotarsal joint (Dunn's procedure in flat foot), removing the entire scaphoid and transplanting the extensor proprius hallucis.

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12. Perthes, G.: Ztschr. f. Chir. **51**:106 (Jan. 19) 1924.
13. Dunn, N., and Stuart, F. W.: Brit. J. Surg. **11**:533 (Jan.) 1924.
14. Stern, W. C.: J. Bone & Joint Surg. **6**:459 (April) 1924.
15. Stuart, F. W.: J. Bone & Joint Surg. **6**:360 (April) 1924.

Stabilization of the Foot by Means of Partial Astragalectomy.—Crainz [16] reports seven cases of arthrodesis of the foot accomplished by removing the astragalus and reimplanting it, either wholly or partially. Six of the cases presented an equino varus deformity and one an equino valgus. He believes that this method is much superior to total astragalectomy without replacement. Only that portion of the astragalus is replaced for which there is a space left after complete correction of the deformity and the cavus has been accomplished.

[ED. NOTE.—Crainz is evidently unfamiliar with the work of Hoke, who, we believe, was the originator of this procedure and has so carefully described the various details necessary for its success. It is interesting, however, for this reason, to note that another mind has apparently been following these same channels and has arrived at the same conclusions.]

Treatment of Poliomyelitis After the Acute Stage.—Legg's [17] advice surely ought to be sound, based as it is on an observation and direction of the after-care of over 2400 patients in connection with the work of the Harvard Infantile Paralysis Commission. The main points that he makes are: 1. Absolute rest, varied applications of heat, prevention of muscular contractions by light retentive apparatus are indicated in the acute stage while sensitiveness persists. 2. Physiotherapeutic treatment under the supervision of an orthopedic surgeon should begin as soon as the acute symptoms subside. 3. Muscle training, beginning as soon as the sensitiveness is gone, should be continued far into the chronic stage. 4. The subcutaneous tenotomy of the Achilles' tendon has often resulted in weakening the calf group and an actual calcaneus deformity. The tendon should be stretched wherever possible by splint or wedged plaster, and if it is ever divided, it should only be done by an open lengthening and suture. 5. Tendon transplantations may usually be safely performed after the first year, since in most cases muscle balance is by this time well established. The transplanted muscles are always somewhat weakened by the operation, and subsequent massage and exercises are extremely important. The results are much better when this subsequent muscle training is carried out by a skilled worker. 6. Bony deformities should be corrected, and often stabilizing operations performed before tendon transplantation are undertaken. 7. Astragalectomy performed in well selected cases produces a stable foot in good position for weight bearing. Its disadvantages are that it shortens the leg (which is often short already) about three-fourths of an inch (19 mm.). The best function is obtained in many cases of unstable feet by the architectural arthrodesis of Hoke.

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16. Crainz, S.: Policlinico **31**:1-7 (Jan. 15) 1924.
17. Legg, A. T.: J. Bone & Joint Surg. **6**:194 (Jan.) 1924.

Legg [17] emphasizes the care that must be exercised in the choice of the operative procedure, and has been greatly impressed by the most unfortunate results of over-fatigue, general rather than special muscle training, and weight bearing without mechanical support in positions that favor deformity.

Obstetrical Paralysis (Erb's Palsy).—Boorstein [18] has contributed a very excellent resumé of this subject which has lately, through the work of Alfred Taylor, Sever, and Turner Thomas, been receiving much attention. Boorstein's conclusions are as follows:

1. Obstetric brachial paralysis is due to stretching or tearing of the cervical nerve roots of the brachial plexus. 2. It is almost always associated with a difficult labor, in many instances forceps having been used. 3. The condition occurs in boys as frequently as in girls, and the right side is more frequently affected than the left. Affection of both arms is very infrequent. 4. The upper arm type is due to injury of the suprascapular and the fifth and sixth cervical nerves. It is much more frequent than the lower arm type. 5. The whole or lower arm type is due to injury of the entire plexus. 6. Vertex presentation shows the larger percentages of occurrences of both types of cases. 7. Improper management of the shoulder is responsible for many cases, hence, they may be prevented by the obstetrician. 8. If these cases are treated early and properly one may expect in the mild cases a good recovery in three or four months. 9. The more severe cases will require about six or seven months for complete recovery. 10. Nerve operations are indicated if no advance is made in four months. After that period, if sufficient improvement is noticed, one may wait four months more, provided, of course, appropriate treatment is continued. 11. The shoulder should be immediately put up in a splint or brace to prevent stretching of the paralyzed muscles and contractures of the unopposed muscles. 12. The support must be kept up for a very long time, eight or nine months, as deformities may occur. Of course, massage and exercises are begun early. 13. Even in the whole or lower arm type one may try conservative treatments for a while and then resort to a plexus operation. The result is not so discouraging as some text books would lead us to believe. 14. The deformity at the shoulder, viz., the adduction and internal rotation, can easily be corrected by tenotomies. 15. The pronation of the forearm can be corrected by a muscle transplantation. 16. A patient suffering from this affection should be under proper observation at least until the age of 10 years, as a slight recurring deformity may present itself.

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18. Boorstein, S. W.: Obstetric Brachial Paralysis (Erb's Palsy), J. A. M. A. **82**:862 (March 15) 1924.

Spastic Paralysis. A New Operative Procedure in the Treatment of Spastic Paralysis and its Experimental Basis.—Royle,[19] working with Professor Hunter, found that by section of the trunk of the abdominal sympathetic, the hypertonicity of the voluntary muscles of the lower limb was greatly decreased. This suggested the application of this operation to cases of spastic paralysis. Two patients were operated on. They were both cases of spastic hemiplegia, one of fourteen years' duration. In the first case, by a linear incision in the flank parallel to the spine, a dissection was made; after identification of the erector spinae, quadratus lumborum, and edge of the psoas, and blunt dissection between the psoas and post peritoneal fat, the sympathetic trunk and ganglia lying close to the bodies of the vertebrae were finally identified. Two white rami from the second lumbar were divided, and two gray rami running to the second, third, and fourth lumbar nerves were avulsed. The trunk itself was divided immediately below the fourth lumbar ganglion. By this procedure, the gray rami communications to the fifth lumbar and sacral nerves were cut off. There was undoubted and marked improvement in the symptoms. Fifty-four days after the operation, the patient could relax his limb in a nearly normal manner when walking. The knee jerks were nearly equal, although an ankle clonus persisted on one side. In the second case, the cervical sympathetic trunk was attacked, the gray rami to the whole branchial plexus being avulsed. In two weeks there was a marked gain in voluntary control of the arm.

[ED. NOTE.—Since this report of Hunter and Royle's work, there has quite naturally been the keenest interest excited in this original procedure. One great American surgeon who has visited Australia is reported to have spoken of this work as representing the greatest advance in surgery in the last twenty-five years. As far as the editors can ascertain, the operation is based on the assumption, which we believe is not universally accepted by all physiologists, that the sympathetic fibers are responsible for the so-called postural tonus. By the motor and sensory nerve mechanism we accomplish a movement, but it is the sympathetic system which maintains a postural tonus once a given position has been attained. If this assumption is true, there would seem to be a sound basis for the procedure, and in Hunter and Royle's reported cases the "proof of the pudding seems to be in the eating." Many more cases we believe are soon to be reported by Royle, and several patients have already been operated on in this country by various surgeons, and one at least by a different method of approach to the lumbar sympathetic trunk,—namely, the abdominal. We have no intention of questioning in any way the value of this brilliant work, but we should

19. Royle, N. D.: M. J. Australia **1**:77 (Jan. 26) 1924.

like to see only a limited number of carefully selected cases in which operations were undertaken only by very well qualified surgeons, who will acquire, if they do not at present possess it, the accurate anatomic knowledge necessary; this is advocated both for the sake of the patients and for the sake of the future of the method. The operations are admittedly difficult, and may be prolonged. Affections of the upper neuron, which are called cerebral paralysis, frequently involve all four limbs, certainly commonly involve both lower limbs. Two or four separate operations with the suggested technic must, therefore, be performed. In our experience, these cases are poorer operative risks than the normal child. Our minds must be open to receive, and skilled hands must be ready to take advantage of, this ray of hope. Time alone, however, can determine whether or not the desired result will be permanent and whether, if it shall prove to be so, other functions of these sympathetic fibers, perhaps more important than postural tonus, have been lost through their division and avulsion.]

ARTHRITIS

Infectious Arthritis.—Swift and Boots[20] have been conducting elaborate experiments bearing on the etiology of arthritis. They now report that they have been unsuccessful in their efforts to sensitize the joints of rabbits by the injection of small doses of killed non-hemolytic streptococci or by extracts of the same. Subsequent intravenous injection of homologous living bacteria produced involvement of the untreated as well as of the treated joints in the same animal.

Moench,[21] on the basis of clinical and experimental evidence, concludes that the cervix uteri may act as a focus of infection in the production of chronic arthritis. The streptococcus was found to play an important pathogenic role, while the saprophytic organisms were relatively unimportant. Experimentally, the aniline dyes have been shown to possess a powerful bactericidal action on these organisms.

Shea[22] has made a study of thirty cases of chronic arthritis with special reference to the etiologic rôle played by the seminal vesicles as foci of infection. He feels that there is no sure way of determining whether the vesicles or other regions of the body constitute the harbor for the infective agents, and that it is only by careful general examination and eradication of all possible foci that results can be obtained. His cases fell into two groups; in one, the indications pointed to other areas as the foci of infection, and the seminal vesicles had been over-

20. Swift, H. F., and Boots, R. H.: J. Exper. M. (Nov.) **38**:573, 1923.

21. Moench: J. Lab. & Clin. Med. **9**:289 (Feb.) 1924.

22. Shea, D. E.: Seminal Vesicles in Arthritis, with a Discussion of Symptomatology and Surgical, and Nonsurgical Treatment, J. A. M. A. **82**:274 (Jan. 26) 1924.

looked, while in the second group the vesicles had been treated to the neglect of other regions where foci were present. He states that early treatment of the infected vesicles is essential for beneficial results. Surgical intervention, consisting of vesiculotomy, was employed only in very acute conditions when the contents could not be expressed; also, in a case where the vesicles were hard and indurated, and producing much discomfort.

Hypertrophic Arthritis.—Willis,[23] writing on the subject of hypertrophic arthritis, states that the changes incident to the disease are to be regarded as the reaction of bone and joint structures to the wear and tear of life. They are more pronounced in certain types of individuals and are aggravated by continual local irritation of any character. His own observations bear out the contentions of Goldthwait, Swaim, and others, that the heavy type of individual is more susceptible to the disease than the slender, but they do not support the statement that it occurs only in advanced age and that it is rarely found in the slender type. Hypertrophic changes are rarely noticed before the thirty-fifth year, but they are progressive thereafter. They may exist to a marked degree without clinical symptoms, and the bone changes are permanent. Treatment should be directed toward the removal of all possible sources of continued irritation. These include mechanical strain, focal infections and absorptions, any or all of which factors may be present in a given case.

Glissan,[24] writing on the surgical treatment of hypertrophic or osteoarthritis of the hip joint, distinguishes two groups of cases. In the first group, in addition to the local process in the hip, the general health is impaired. There are loss of weight, anemia, and other signs of illness. These patients are usually under 40 years of age. The second group is composed of individuals who are usually over 40 years of age, and whose general health is excellent. They are usually putting on weight, and have no complaint beyond that of their local joint condition. No septic foci are to be found, but there is evidence of arterio sclerosis. In considering treatment, he states that the restoration of the joint to its normal condition is obviously impossible, but that the relief of symptoms is largely possible. The key note of the treatment is rest. In the early stage of the disease he uses a short plaster spica, the hip being fixed in extension and slight abduction. Crutches are permitted, with a high sole on the unaffected leg. Later, a walking caliper splint is applied. In the second stage of the disease, when the pain is more constant, recumbent treatment is required. This is continued until all of the tenderness about the joint has disappeared; then manipulation is per-

23. Willis, T. A.: J. Bone & Joint Surg. **6**:316 (April) 1924.
24. Glissan, D. G.: J. Australia **2**:561 (Dec. 1) 1923.

formed under an anesthetic to correct deformity, and the hip is fixed in a short plaster spica. The after treatment is the same as in the first stage of the disease. In the final stage of fixed adduction and flexion deformity with severe pain, operative treatment may be considered in selected cases. Various procedures have been advocated, pseudo-arthrosis as recommended by Jones, excision of the head as advised by Platt, arthroplasty, arthrodesis, and cheilectomy. The author considers the latter procedure, with removal of osteophytes, as one giving only temporary relief; he thinks that arthroplasty has but few adherents, and his own preference is for arthrodesis, employing Albee's technic.

[ED. NOTE.—The editors endorse the viewpoint of Glissan in regard to the treatment of hypertrophic arthritis of the hip. Operative treatment is rarely indicated in these cases; not only because, in general, they constitute poor surgical risks, but also because a better result, both as regards function and relief of pain, is usually to be obtained by the use of rest in one or another of its modalities. Operation, however, has its indications in carefully selected cases, but our preference then is for a procedure such as excision of the head and remodelling of the neck, rather than for arthrodesis. Ankylosis is obtained with difficulty in hypertrophic arthritis because of the sclerosing and the degenerative processes present in the bones. In addition these old patients do not tolerate well the long period of fixation which the attempt to obtain it entails.]

SYPHILIS

Syphilitic Bursitis.—Lane [25] reports two cases of prolonged bursitis in which the Wassermann reactions were positive, and which cleared up under antisyphilitic treatment. He has found other cases reported in the literature. He concludes that syphilis may invade any structure in the body and at any age. Manifestations not only of secondary but also of tertiary and congenital syphilis are not infrequently encountered in the subcutaneous bursae and in the tendon sheaths. They may be recognized from the history of syphilitic infection, the characteristics of the process itself, the presence of a positive Wassermann reaction, and the prompt disappearance of symptoms under specific therapy. A positive diagnosis is possible only when several of the previously mentioned signs are obtained, but in case of doubt the therapeutic test should always be tried.

SUPPURATIVE MYOSITIS

Avoni [26] reports a case of infectious myositis, in which one of the thigh muscles was involved. The organism was *Staphylococcus*

25. Lane, J. E.: Syphilitic Bursitis (Leutic Bursopathy of Verneuil), J. A. M. A. **82**:852 (March 15) 1924.

26. Avoni, Dott. Aldo: La Chir. deg. Org. d. Mov. **8**:189 (Dec.) 1923.

pyogenes-citreus. The diagnosis is based chiefly on a swelling, corresponding to the shape of the affected muscle, and on the painful contraction of the muscle that holds the limb in a position of deformity. The treatment is surgical, and the prognosis is usually good. The condition apparently occurs in Japan much more frequently than elsewhere.

OSTEOMYELITIS

Beye [27] presents several sound arguments, backing them up with five cases, against the extensive subperiosteal resection of bone in osteomyelitis. In the five cases reported this procedure was followed, and the illustrations together with the clinical histories serve very well to indicate what the author regards as fundamental errors in the surgical treatment of osteomyelitis. It is impossible at the time of operation to determine the extent of bone necrosis, and necrotic bone may well play an important part in the progress of bone repair. It is a mistake to assume that regeneration of bone will always take place adequately from the periosteum remaining after resection. After extensive resection, deformity is likely to develop during the period of bone regeneration.

Rovsing [28] reports twenty-three cases of chronic osteomyelitis successfully treated by the use of autogenous vaccines. The infectious agents were *Staphylococcus aureus* and *albus*, and typhoid and paratyphoid.

Tinozzi,[29], from a study of eight cases of osteomyelitis with sinuses, reports excellent results from the use of vaccines. Autogenous vaccines are preferable. In his series, one patient was infected with *Staphylococcus albus*, five were infected with *Staphylococcus aureus*, one had a double infection, *albus* and *aureus*, and the eighth case was one of a streptococcus infection.

Phemister [30] has observed four cases of localized osteomyelitis in persons having osteomyelitis elsewhere in the body; these secondary foci of infection had developed with little or no symptoms. Phemister calls them "silent foci." He shows that osteomyelitis may develop painlessly, and be present for weeks or months without local symptoms. Certain localized symptomless areas of bone sclerosis may be accounted for as former silent foci of osteomyelitis. There is no reason to suppose that these silent foci have any relationship with the painless abscesses about the roots of the teeth. A routine search for symptomless foci of infection is advisable in cases of osteomyelitis, especially in those cases in which the disease is due to the staphylococcus.

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27. Beye, H. L.: Surg., Gynec. & Obst. **37**:732 (Dec.) 1923.
28. Rovsing, T.: Hospitalstid. **66**:563 (Aug. 8) 1923.
29. Tinozzi, F. P.: La Riforma Med. **40**:149 (Feb. 18) 1924.
30. Phemister, D. P.: Silent Foci of Localized Osteomyelitis, J. A. M. A. **82**:1311 (April 26) 1924.

Henderson [31] regards "chronic proliferative sclerosing osteitis" as a clinical entity, and shows that it may easily be confused with syphilitic osteitis, with Paget's disease, with osteitis fibrosa, and with sarcoma. He has observed the clinical course of thirty cases, in which thirteen patients were operated on and seventeen were not operated on. The operation was designed to improve the blood supply in the hard, eburnated bone and in the medulla. In spite of resection and trephining, the process is likely to recur. Of the patients operated on, nine are known to have been relieved, one was not improved, two received temporary benefit, but had the symptoms recur, and five were not traced. Henderson believes that the process is that of a low grade bone infection. The average duration of symptoms in the group of cases he has studied was six years; one patient had had symptoms for twenty-five years. Trauma might, with reason, have played a part in the origin of the process in seven of the cases, and infectious disease in eight; the Wassermann test was negative in all but one case. The important symptom is pain.

NEOPLASMS

William B. Coley [32] gives his views on the prognosis of sarcoma of the long bones in an interesting article. He reports sixty cases and draws some very practical conclusions. He believes that it would seem necessary to modify the opinion held today by numerous leading pathologists, that giant cell sarcoma is always benign and that it never gives rise to metastases. If one assumes that all the cases in his series placed in the benign giant cell group, in which metastases later developed and the patient died, were cases of mistaken diagnosis, then it is possible to maintain still that all giant cell tumors are benign. However, in many cases in his series, the diagnosis of benign giant cell tumor had been made by the most competent pathologists, who had studied bone tumors most carefully. It is to be understood that Coley feels that diagnosis is difficult, and that statements as to the absolute benignity of giant cell tumors should still be taken with a grain of salt. We must admit too, that the treatment of giant cell sarcoma by radium or the roentgen ray is at present in an experimental stage, and that the results thus far attained do not warrant our abandoning surgical treatment,—that is, surgical curettage. At present, the best plan for the treatment of giant cell tumors would seem to be the curetting of all tumors that it is possible to curette, swabing out the cavity with pure phenol and alcohol, or zinc chlorid, packing the cavity with gauze to control hemorrhage, protecting the limb with a plaster of Paris dressing to prevent pathologic fracture,

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31. Henderson, M. S.: Chronic Sclerosing Osteitis, J. A. M. A. **82**:945 (March 22) 1924.

32. Coley, W. B.: Ann. Surg. **79**:321 (March) 1924; **79**:561 (April) 1924.

and keeping the cavity clean with dressings of surgical solution of chlorinated soda. In addition to this surgical treatment, the patient should have systematic treatment with the mixed toxins of erysipelas and *Bacillus prodigiosus,* and should be given at least one massive dose of radium. If the disease progresses, a second curettage, even a third, should be given, and if radium is not available, the roentgen ray should be used. If the disease still progresses, amputation may be considered. Perhaps primary amputation should never be done for giant cell sarcoma. Clinical evidence of malignancy, such as the rapid growth and breaking through of the bony shell should outweigh the purely histologic evidence that a giant cell tumor is benign.

[Ed. Note.—It seems to the editors that this contribution from Coley is well worth careful consideration. His long experience with these tumors of the bony tissue of the body, as well as his careful study of an enormous amount of material collected throughout several decades, entitles him to speak with the only voice that should count in these matters, that of clinical experience. All too frequently the pathologic report is regarded as final, and amputation is done with the belief that a life is being saved by amputation; later, it develops that the tumor was benign or that the malignancy of it prevented the amputation from being of the slightest use.]

Roederer [33] is inclined to believe that the true bone cyst constitutes a clinical entity which is in no way related to bone tumors, von Recklinghausen's disease, osteitis fibrosa, etc. He admits that nothing is known as to the cause of bone cysts. He believes that the cyst is formed by a process of bone absorption going on within the shaft. This process of absorption may be due to trophic disturbance, to traumatism, or to attenuated infectious process. He believes that our feet are on firm ground when it comes to the treatment of bone cysts. Any operative procedure that will open the cyst will be followed by healing of the cavity; indeed, spontaneous fracture will often be followed by healing of the cyst. Filling the cavity with grafts or fatty tissue is not at all necessary, although an osteoperiosteal graft may hasten the process of repair.

Bloodgood [34] reports that there is ample evidence to prove that the bone cyst may heal spontaneously. He believes that the locality of the cyst should be frequently studied by means of the roentgen ray in order to determine whether the cyst is enlarging or ossifying. He advises rest in bed, with or without fixation, for a period of months to aid the healing process.

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33. Roederer, C.: Rev. d'orth. **10**:551 (Nov.) 1923.
34. Bloodgood, J. C.: J. Radiol. **5**:3-9 (Jan.) 1924.

Hundling [35] describes in a carefully written paper the nature of ventral tumors of the sacrum, the so-called Middeldorpf tumors. These growths are definitely encapsulated, are usually attached to the periosteum, and have a tendency to erode the bone. They exert their greatest pressure on the neural side of the sacrum, and not on the rectal side. Remains of the lower neural canal and of the postanal gut seem to furnish the basis for these tumors. There is controversy as to their origin, whether it is monogerminal or bigerminal. All the body tissues may be represented in the growth. These tumors seldom metastasize, but may cause death by infiltration. They cause few if any symptoms or signs besides that of pain resembling sciatica. Constipation may also be a symptom. Roentgen-ray examination usually does not reveal the growth. Treatment consists in the removal of the growth and the use of radium.

Carey [36] has made a report on the necropsy findings in a case in which there was a "multiple bilateral traumatic periosteal bone and callus formation of femur and left innominate bone." His report is of value because of the detailed histologic study of the tissues.

FRACTURES

Method of Obtaining Extension in Fractures of the Femur.—Byford [37] describes a method of securing traction in cases of fracture of the femur when caliper extension and operative treatment are refused. He applies to the lower leg, from ankle to knee, a circular plaster casing, and prolongs the anterior portion upward to a point several inches above the patella by incorporating in it a fiber board reinforcement. The knee is fixed in flexion, and then traction is applied to this upper point of the casing, with a resultant pull directly in the axis of the femur. He obtained very satisfactory alinement in two cases by the use of this method.

[ED. NOTE.—This method seems rather ingenious and merits trial when, for some reason, extension by caliper tongs or adhesive strips is not possible. Great care would be necessary to avoid the formation of pressure sores on the posterior surface of the leg. The possibility of a contraction of the knee in flexion would also have to be taken into consideration, although the risk ought to be slight.]

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35. Hundling, H. W.: Surg., Gynec. & Obst. **38**:518 (April) 1924.

36. Carey, E. G.: Multiple Bilateral Traumatic Parosteal Bone and Callus Formations of the Femurs and Left Innominate Bone, Arch. Surg. **8**:592 (March) 1924.

37. Byford, W. H.: J. Bone & Joint Surg. **6**:471 (April) 1924.

Fractures of the Leg and Ankle.—Ashhurst and Crossan [38] have completed careful records of the end-results in one hundred fractures of the leg and ankle. The functional results have been tabulated in strict accordance with the recommendations of the Fracture Committee and are recorded as good in 72 per cent. of the cases, moderately good in 26 per cent., and bad in 2 per cent. Of the twenty-six patients with moderately good function, seventeen had lessening of endurance, ten had pain at various times, four were lame, three had swelling, and three had limitation of motion. There was shortening in four cases, but there was no case of nonunion. The period of disability for fractures of the shaft of the leg bones averaged three and eight-tenths months in cases of simple fractures and five and one-half months in compound fractures. This is one month less and six weeks less than the average periods of disability for corresponding types of fractures as tabulated by the American Surgical Association. The disability periods for simple and compound fractures of the ankle were approximately the same as those for fractures of the bones of the leg. The authors urge early reduction of displacement in all cases and stress the importance of anatomic reposition, especially in fractures of the ankle. They consider Stimson splints of plaster of Paris far superior to circular plaster casts, and also recognize the special advantages of the Delbet plaster in permitting active movements of the knee. Skeletal traction with the Steinmann pin has given admirable results in compound and difficult simple fractures.

Stevens,[39] writing under the title, "Compression Leverage Fractures of the Ankle Joint," divides these cases into the eversion and inversion types. Leverage fractures of the ankle under compression are all, in reality, of the same etiology, but they differ in the variation as to the distribution of the force and the intensity of the strain. The author states that the majority of these fractures do not deserve the bad reputation that they have acquired. The bad results usually follow improper treatment, especially that of prolonged immobilization. He believes that the solution of the problem is to be found in active and passive movement from the very beginning, personally supervised by the attending surgeon. In cases of fracture of this type without complications, the patient should be able to return to light work in from four to seven weeks with a practically normal foot, except for swelling, which may persist for a long time.

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38. Ashhurst, A. P. C., and Crossan, E. T.: Prognosis and Treatment of Fractures of the Leg and Ankle: End-Results in One Hundred Patients. Arch. Surg. **7**:601-632 (Nov.) 1923.

39. Stevens, J. H.: Surg., Gynec. & Obst. **38**:234 (Feb.) 1924.

[ED. NOTE.—We believe that the end-result figures published by Ashhurst and Crossan are of great interest, covering as they do a large number of cases. The average disability periods for both the fractures of the bones of the leg and those of the ankle are the best yet reported, so far as we know. We agree with Stevens that, in the case of fractures of the ankle, there is too much tendency to leave these cases in plaster and to consider the roentgenologic demonstration of good reduction as the last word in active treatment, while the preservation of the normal weight bearing lines and of a good range of movement are of even greater importance than anatomic reposition. We cannot agree to any general statement to the effect that these fractures are not serious, or that the disability period should not exceed a period of from four to seven weeks in the majority of cases. More fact and less theory are needed here, and this can be obtained only by means of a serious and widespread effort to run down and examine old cases, a study which is to be undertaken shortly by the Fracture Committee of the College of Surgeons.]

Old Fractures of the Ankle.—Geist [40] reports his findings and treatment in a group of thirty-five cases of old fractures of the ankle. These comprised nearly all ages and both sexes. The length of time since injury varied from six months to ten years. The complaints included pain, swelling, stiffness, limitation of capacity to walk, and inability to follow previous occupations. Thirteen patients had had adequate treatment, but in twenty-three cases it had been inadequate. The cases were classified as inversion type, 6 cases; eversion type, 14; posterior displacement, 11; and atypical, 4. The symptoms were due to a combination of misalinement, atrophy, and rigidity. In some, there was shortening of the Achilles' tendon. The treatment naturally depends on the severity of the symptoms and the type of the deformity. In some, lengthening of the Achilles' tendon is sufficient; in others, especially in the arthritic cases, arthrodesis is required when an ankle brace will not relieve. In cases of inversion deformity a supramalleolar osteotomy gives good results. In cases of backward displacement, treatment is more difficult. If refracture is performed, it is difficult to maintain a position of correction, and in four of these cases the author has performed an arthrodesis for the relief of pain.

Transcalcaneal Surgical Approach for Fractures of the Ankle.—Blanchard [41] describes the transcalcaneal surgical approach to the ankle which he has used with good result in one case, although his patient died later of an intercurrent disease before the final result could be ascer-

40. Geist, S.: Old Fractures of the Ankle, J. A. M. A. **82**:960 (March 22) 1924.

41. Blanchard, G.: Presse méd. (Feb. 6) 1924.

tained. The operation has also been described by Algave, although Blanchard's case antedates his. The incision is especially suitable for certain fractures of the ankle requiring open reduction, although it may also be used in other conditions as a means of approaching the tibia-astragaloid and subastragaloid joints. Its advantages over other incisions, as stated by Blanchard, are wide exposure with opportunity to explore thoroughly the ankle joint by displacing the foot forward, the slight amount of damage done to important structures, and rapid functional recovery after operation. His own patient began to bear weight on the foot on the sixth day. The operation is performed as follows. The patient is placed in a three-quarters prone position, with the ankle resting on a sand bag. Two incisions three inches long are made, one on either side of the heel, in front of the Achilles' tendon and terminating below at the plantar margin. The lower ends of the incisions are then connected by a posterior horizontal incision. The plantar tissues are stripped from the os calcis and the flap turned downward and forward. The posterior portion of the os calcis is then sectioned vertically with a Gigli saw, and the posterior fragment with the attached Achilles' tendon and skin covering is retracted upward. The deep fascia at the back of the ankle is divided in the median line, the long flexor of the great toe is retracted inward, the posterior portions of the deltoid and capsular ligaments are stripped to the sides, and the joint entered. For wide exposure, the foot should be dislocated forward. In closing the wound, the deep structures are approximated with a few catgut sutures; the fragment of os calcis is replaced and fixed with a nail, and the skin approximated.

[ED. NOTE.—From the anatomic standpoint this approach is neat, but from the functional standpoint the chance of impairment would appear to be great. As a matter of fact, in the antero median and the postero medial and postero lateral incisions, we have excellent methods of approaching the ankle by routes which are chiefly subperiosteal and hence little damaging to function. The indications for the transcalcaneal route would therefore indeed seem few.]

Fracture of the Os Calcis.—Sneed,[42] reporting on fractures of the os calcis, calls special attention to the displacement. When the injury is produced by a fall, the astragalus is driven downward into the os calcis, widening the heel and lowering the external malleolus. The lower end of the fibula impinges upon the os calis and is thus transformed into a weight bearing bone, thereby producing pain. The author emphasizes the necessity of more careful treatment immediately after the injury. The deformed bone should be properly molded and reshaped as it is advised by Cotton and others.

42. Sneed, W. L.: J. Bone & Joint Surg. **6**:157-161 (Jan.) 1924.

Epiphyseal Displacements. Smith [43] has looked up the end-results in thirty-three cases of epiphyseal displacement. Of these patients, there were twenty-eight boys and five girls, and the average age was 12 years. Only eight were below the age of 10, the majority of these patients suffered from injuries of the lower epiphysis of the humerus. On examination, he found that 15 per cent. showed premature ossification. This appeared in one case as promptly as six months after injury, and in another as late as two and one-half years. Slight retardation of growth was common. It was present in 33 per cent. of injuries to the epiphyses of the long bones, and in two cases the shortening was sufficient to cause a decided deformity. Retardation of growth may persist even without premature ossification, and the evidence indicates that compensation for the shortening at a later period seldom occurs. In injuries of the lower radial epiphysis, with retardation of growth, there frequently occurs a similar compensatory process in the ulna, so that it fails to outgrow the radius. In cases of unreduced epiphyseal displacement, there seems to be a strong tendency for natural correction of the deformity to take place, with growth.

Late Ulnar Nerve Palsy.—Miller,[44] from a study of the literature and a considerable personal experience, concludes that in late ulnar nerve palsy the primary cause in practically all cases is a fracture of the elbow in childhood, usually occurring between the third and fifth years. Although occasionally the site of injury may be at the internal condyle or in the supracondyloid region, in the vast majority of cases the fracture line begins laterally just above the epicondyle and passes obliquely downward and inward into the joint, causing a complete separation of the capitellum. The fragment is displaced laterally and forward, and the fractured surface is rotated outward. Accurate replacement by manipulation is impossible, and nonunion of the condyle frequently results. The growth of the humerus on this side is interfered with and a cubitus valgus gradually develops. As the deformity increases, the olecranon impinges against the medial condyle, and the ulnar groove is converted into a shallow depression. The nerve itself is displaced from its bed and becomes subjected to stretching when the elbow is flexed and extended and to repeated slight traumas, which, in time, lead to a partial or complete ulnar palsy. The paralysis may appear as early as three years or as late as forty years after the injury, but in the majority of cases (40 per cent.) it comes on between the twentieth and thirtieth year after the fracture. Prevention of this condition would appear to lie in a greater effort to secure accurate reposition of the fragments in these childhood fractures, with resort to the operative

43. Smith, M. K.: Ann. Surg. **79**:273 (Feb.) 1924.
44. Miller, E. M.: Surg., Gynec. & Obst. **38**:37 (Jan.) 1924.

method whenever it is necessary. The ulnar palsy, when it appears, necessitates operative treatment, either with correction of the deformity or transplantation of the nerve to the flexor surface of the elbow.

[ED. NOTE.—The condition of late ulnar nerve palsy, although not frequently encountered, is of considerable importance, especially from the medicolegal standpoint, and it is interesting to have on record this convincing account of the mechanism by which it is produced.]

Fracture from an Industrial Standpoint.—Ryerson,[45] writing on the treatment of fractures from an industrial standpoint, emphasizes the advantages of special apparatus such as the various traction splints, over the simple plaster of Paris cast. In oblique fractures of the shaft of the femur, reduction cannot be maintained in plaster. Overriding and angulation can easily occur and with very little external evidence of their presence. On the other hand, with traction, good position is readily obtained, and the traction splints also permit the early use of physiotherapy, a feature of considerable importance.

DISLOCATIONS

Luxatio Erecta of the Shoulder.—Bernardbeig and Cherry[46] report two cases of the rare form of shoulder dislocation known as luxatio erecta, in which the arm is abducted nearly vertically over the head and flexed in this position. From experimental work with the cadaver, they conclude that the position results from a position of extreme abduction and internal rotation of the arm. Avulsion of the attachments of the muscles inserted into the greater tuberosity also appears to play an important part. The deltoid and latissimus dorsi muscles exercise a deforming influence on the humeral head when the arm is abducted to the point where the axis of the humerus passes above the plane of the muscles. If the head leaves the glenoid at this point, it is drawn by these muscles down toward the side of the thorax, while the elbow is at the same time raised. Reduction in the author's cases was readily accomplished by traction upward on the arm in the axis of the limb, with direct upward pressure on the humeral head in the axilla, followed by adduction of the arm to the side.

Costochondral Dislocation.—Oudard and Jean[47] have made a clinical and experimental investigation of dislocation at the costochondral junction. They conclude from a study of the literature that no case has yet been reported in which it was shown beyond doubt that this condition was present. It seems impossible by experimentation with the cadaver to produce the lesion, the usual result being a fracture of the costal

45. Ryerson, E. W.: J. Bone & Joint Surg. **6**:188 (Jan.) 1924.
46. Bernardbeig, J., and Cherry, R.: Presse méd. **32**:149 (Feb. 16) 1924.
47. Oudard, and Jean, G.: Rev. de Chir. **61**:540, 1923.

cartilage. The authors have operated in several cases which clinically seemed to be cases of dislocations, and invariably they have found a fracture of the costal cartilage instead.

BONES AND JOINT SURGERY

A New Incision for Clavicle Operations.—Soutter [48] suggests an incision for approaching the supraclavicular region, lower neck, upper chest, and outer sternal region in cases where it is desirable to avoid a visible scar. The incision extends from the spine of the scapula over the shoulder, crossing the clavicle just proximal to the acromioclavicular joint; it then passes downward anteriorly to the level of the fourth rib just internal to the anterior axillary line; at this point, it turns inward at right angles for a distance of one inch. It will be seen that the line of incision may easily be covered by a dress shoulder strap. The author has used this incision in one case only, but his exposure was such that he ventures to suggest it as an approach to the regions mentioned.

A Case of Snapping Shoulder.—Bristow [49] describes a case of snapping shoulder relieved by resection of the muscle fibers passing from the short head of the biceps to the long head, and coming in close relation to the lesser tuberosity.

Recurrent Dislocation of the Shoulder.—Oudard [50] describes a new operation for recurrent dislocation of the shoulder. The central idea of this operation is to create by means of a bone graft a solid block to forward displacement of the humeral head. The incision is made in the deltopectoral groove, extending as far as the coracoid process, then outward along the inferior border of the clavicle to the acromioclavicular articulation. The attachment of the deltoid to the clavicle is divided and the flap retracted outward. The coracoid is sectioned 1.5 cm. from its tip, and this with its attached muscles is turned downward. The subscapularis muscle is then freed and its tendon with the underlying capsule is sectioned. These flaps are sutured in an overlapping manner. A bone graft 4 cm. long by 3 cm. wide and 1 cm. thick is cut from the tibia and one end sutured by wire to the base of the coracoid and the other end to the tip of the coracoid, which still retains its muscle attachment. The graft is surrounded by several, small, osteoperiosteal grafts. The deltoid is replaced and sutured, and the skin incision closed. The coracoid is thus prolonged outward and downward and acts as a mechanical block to displacement. The author reports five patients treated by this method, all with good results thus far; the oldest patient was operated on two years ago.

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48. Soutter, Robert: A New Incision for Clavicle Operations, J. A. M. A. **82**:1179 (April 12) 1924.

49. Bristow, W. Rowley: J. Bone & Joint Surg. **6**:53 (Jan.) 1924.

50. Oudard, M.: J. de chir. **23**:13 (Jan.) 1924.

[Ed. Note.—The factors on which this operation depends for success are not under control. The coracoid process does not possess sufficient osteogenetic power to invariably insure union with a bone graft. To overcome this difficulty, the author uses osteoperiosteal grafts, thereby introducing the possibility of too much of an overgrowth of bone, but not necessarily insuring bony union. Furthermore, is it sound to displace muscular attachments a distance of 4 cm.? Sooner or later the strong muscles attached to the coracoid process might fracture it.]

Excision of the Elbow.—Stoney [51] has reached the conclusion that excision of the elbow in the majority of cases gives better results than arthroplasty or arthrodesis. He does not report his cases in detail, but mentions two patients able to do manual labor after excision.

Fracture of Olecranon Treated by Temporary Pressure Paralysis of Musculospiral Nerve.—Robertson,[52] under this rather misleading title, reports one case of fracture of the olecranon. Not only did the author securely suture the fragments, but he also eliminated muscle pull by producing a temporary paralysis of the musculospiral nerve. This temporary paralysis lasted six and one-half weeks and was produced by pinching the nerve between the fingers for ten minutes. A clamp has now been devised by which the necessary trauma can be brought about in a more accurate manner. The author feels that the principle of temporary pressure paralysis should be extended to the treatment of other fractures.

[Ed. Note.—The same author has previously used temporary pressure paralysis in the treatment of congenital dislocation of the hip. We must give him credit for having the courage of his convictions, but we feel that it is unwise to play with nerve tissue, whose powers of regeneration and repair are so uncertain, especially when equally good results can be obtained without taking such chances.]

Hypertrophy of the Transverse Process of the Seventh Cervical Vertebra.—Sénèque [53] has made an anatomic study of the transverse process of the seventh cervical vertebra, and finds in many cases that it may easily cause compression and irritation of the eighth cervical nerve root. He reports seven cases of pain and weakness of the arm with signs of radicular involvement due to this cause. These cases were treated surgically and the tip of the transverse process resected, with good results in all except one case in which the associated cervical arthritis was not recognized. He approaches the transverse process through a curved incision, with its convexity inward, extending from

51. Stoney, R. A.: Irish J. M. Sc., p. 30 (Jan.) 1924.
52. Robertson, G.: Edinburgh M. J. **31**:86-90 (Feb.) 1924.
53. Sénèque, J.: J. de chir. **22**:113, 1923.

the posterior border of the mastoid to the outer, lower border of the trapezius. The deep fascia is incised, the cords of the brachial plexus freed and retracted, and the first rib identified. This is followed posteriorly to the transverse process of the seventh cervical, which is felt projecting just above the first rib. This is freed and its tip resected.

[ED. NOTE.—The transverse process of the seventh cervical bears the same relation to the first rib as the transverse process of the fifth lumbar bears to the ilium. Faulty mechanical relations occurring in either region respond in the great majority of cases to correction of posture; it is rarely necessary to resort to surgery.]

Indications for Internal Splinting of Spine.—Magnuson [54] reports the use of a heavy bone graft, which is fastened to the spinous processes by ivory screws, or, if this is impossible, by heavy braided silk. He says it will give immediate immobilization, immediate relief from pain, do away with the necessity of uncomfortable body casts, and allow the patient to move freely in bed. Furthermore, the patient is able to assume the upright position within three weeks after the operation. He believes that this type of fixation should be done wherever chronic disabling pain and increasing deformity exists as a result of the following conditions: (1) tuberculosis of the spine; (2) tuberculous caries of the bodies of the vertebrae; (3) fracture of the spine, including (*a*) compression of the bodies, and (*b*) fracture of the articular processes; (4) forward slipping or relaxation of the fifth lumbar vertebra; (5) chronic strain with relaxation of the ligaments when there is malformation at the lumbo sacral articulation with disabling backache.

[ED. NOTE.—There is no room for argument as to the indications for a stabilizing operation on the spine. As to the type of operation to be performed, we must disagree with the author: Hibb's fusion operation brings equally good results and brings them as quickly as the operation suggested. The same may be said of the Albee bone graft. The use of bone screws may be helpful in securing immediate, but temporary, rigid support, but screws cannot be depended on to grip permanently, especially when they are inserted into small bones like the spinous processes. The author, therefore, wisely secures his graft by heavy braided silk sutures. The use of bone screws is the one new point in the article; lateral spinal grafts have long been in use.]

A Report of Fifty-Nine Cases of Scoliosis Treated by Fusion Operation.—Hibbs [55] has observed fifty-nine cases of fusion of the spine in scoliosis due to muscle imbalance long enough to feel sure that further deformity has been prevented. There were two deaths from

54. Magnuson, P. B.: Surg. Gynec. & Obstet. **38**:112 (Jan.) 1924.

55. Hibbs, R. A.: J. Bone & Joint Surg. **6**:3 (Jan.) 1924.

lobar pneumonia and acidosis; all but one case healed by first intention. Back pain was relieved; there was improvement in general health. From six to sixteen vertebrae were fused, and in five cases a secondary operation was performed when the extent of the primary operation was found to be insufficient. The most satisfactory results were obtained when the operation was performed before severe deformity had developed. Excellent results were obtained in nearly half the cases; good results in 34 per cent.; fair in 9 per cent. and poor in four. The poor results were obtained in cases in which there was extensive paralysis and extreme deformity.

The Lumbosacral Region: An Anatomic Study and Some Clinical Observations.—Von Lackum [56] undertook this anatomic study to determine the cause of the selection of this site of injury in the majority of back cases. Thirty bodies were examined. The author reaches the following conclusions: 1. The lumbosacral joint is an unstable mechanism because (*a*) it is the juncture of a mobile and an immobile part; (*b*) the usual means of joint stabilization are at a disadvantage in consequence of a developmental structure designed for the all-four position; (*c*) it is the site of rotating action, which is often asymmetrical, and (*d*) it is the site of tremendous shearing strain. 2. The strain of the joint is always shearing, regardless of position. 3. The shape of the first sacral is of primary importance in the reduction of this strain because of its bearing on the angles that either increase or decrease it. 4. Backache may be caused by an increased angle and a consequently increased strain. 5. Backache, following long bed rest or acute illness, may be the result of so-called normal strain, which cannot be controlled by the weakened muscles. 6. The occurrence of fractures and dislocations in this region is facilitated by the rotating action in the joint. 7. Anatomic deformities in this region are active causes of disability and deformity. 8. Fusion can be done without fear of affecting the usefulness of the part.

[Ed. Note.—While the editors do not disagree with the anatomic explanation of the symptoms of low backache offered by Von Lackum, they are still of the opinion that developmental and postural treatment is capable of permanently relieving these symptoms without recourse to operative procedures in the vast majority of cases.]

Stabilization of the Fractured Femur.—Hildebrand [57] offers a modification of existing methods for improving the function of ununited fractures of the neck of the femur. This modification consists in

56. Von Lackum, H. L.: The Lumbosacral Region, J. A. M. A. **82**:1109 (April 5) 1924.

57. Hildebrand, O.: Zentralbl. f. Chir. **51**:119 (Jan. 19) 1924.

deepening the angle between the greater trochanter and the neck of the femur, and fitting it to the superior margin of the acetabulum.

[ED. NOTE.—The mechanics of this operation do not seem sound unless an ankylosis is obtained. The position of abduction and effective leverage of the glutei can only be retained if the trochanter is transplanted down on the shaft of the femur. As a result of the loss of the head of the femur and a shortened neck, the normal fulcrum is lost and the femur goes into a position of adduction. Transplantation of the gluteal attachment prevents this deformity.]

Osteoplasty of the Femur.—Cunéo and Bloch,[58] under the title given, report an improved technic of bone grafting, which in their hands has given excellent results in cases of pseudarthrosis of the femur with loss of substance. The method is also applicable for use in the closing of any skeletal defect. The keystone of the method is the detaching of a bone graft of considerable size with its overlying periosteum, muscular attachments, and vascular connections intact, thus assuring a living graft. In the case of a pseudarthrosis of the femur, they approach the bone laterally, trim away the interposed fibrous tissue, freshen the ends of the fragments, and open up the medullary canal. The distal fragment is then freed cautiously in order to preserve the muscle attachments on the anterior surface. The shaft is then split longitudinally and the anterior half sectioned horizontally, forming a pedicle graft of the desired length. The pedicle, consisting of muscle, is freed, and the graft mobilized. It is then transplanted by sliding proximally to the defect and is sutured to the ends of the fragments by means of wire passing through drill holes in the graft and encircling the shaft. It is claimed that this graft is capable of osteogenesis. It is not subject to fracture as is the common free graft.

A New Operation for Slipping Patella.—Soutter[59] reports a case of slipping patella relieved by a modified Gallie operation. Instead of fastening the fascia to the internal femoral condyle, the fascial strip was passed through a tunnel in the patella at an angle of 45 degrees with the vertical plane and then through a tunnel in the same direction in the top of the tibia. Nine months after operation there was normal function. The author emphasizes the logic of fastening the fascia to the tibia instead of the femur. The relation between the patella and the tibia remains constant in all positions of the knee joint, while the relation of the patella to the femur changes. By fastening the patella to the tibia, therefore, the danger of stretching the fascia is eliminated.

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58. Cunéo, B., and Bloch, J. C.: J. de chir. **23**:113 (Feb.) 1924.

59. Soutter, Robert: A New Operation for Slipping Patella, J. A. M. A. **82**:1261 (April 19) 1924.

Note on a Possible Sequela After Operation for the Removal of the Internal Semilunar Cartilage.—Dunn [60] calls attention to a case in which a painful neuroma of the patellar branch of the internal saphenous nerve developed in the scar after removal of the internal semilunar cartilage. Excision of the scar was done, and on microscopic examination this was found to contain a typical neuroma.

The Orthopedic Problem of Excision of the Knee.—Calvé and Galland [61] describe an apparatus for the postoperative treatment of cases of excision of the knee. This consists of a hinged and pivoted steel frame which is incorporated in a plaster cast of the leg. The apparatus is applied and the cast made previous to the operation. After operation, the apparatus is adjusted so as to bring the sectional ends of the bones together in perfect alinement.

Pes Cavus.—Laroyenne [62] reports a symposium on the etiology and treatment of pes cavus by the French Orthopedic Society. The chief features of the deformity were recognized as an equinus position of the anterior tarsus with or without a vertical inclination of the os calcis, hammer toes, and metatarsal varus as secondary features. The paralytic type of cavus is usually due to paralysis of gastrocnemius-soleus group, with resulting pes calcaneus and secondary deformity of the anterior foot. However, paralysis of the short plantar flexors with the gastrocnemius intact may also produce the deformity, due to overaction of the long extensors of the toes resulting in dorsal luxation of the toes and depression of the heads of the metatarsals. Cavus deformity may also result from contraction of the plantar fascia, section of the Achilles' tendon, and certain nervous disorders such as spina bifida occulta, hereditary cerebellar ataxia, etc. The deformity may also be inherited. Essential pes cavus is of unknown origin, but with more thorough search for spina bifida occulta, and other etiologic conditions the number of cases of this is being progressively diminished. Cavus rarely begins to cause symptoms before the age of 7, and frequently it is not noticed before the age of 15 years. The complaint is of pain and difficulty in walking, and chronic ulceration. The deformity tends to progress gradually for many years. Conservative treatment by special shoes and apparatus is useful only in the earliest stage of the deformity. After this, operative treatment is required. In the paralytic type it is generally agreed that correction of the deformity alone, without accompanying measures to maintain correction, is useless. For this reason tenodesis or

60. Dunn, Naughton: J. Bone & Joint Surg. **6**:237 (April) 1924.
61. Calvé, J., and Galland, M.: Presse méd. **32**:315 (April 9) 1924.
62. Laroyenne, M.: Rev. d'orthopédie **10**:512 (Nov.) 1923.

transplantation of tendons to reinforce the Achilles tendon is essential. Bone operations such as osteotomies, combined with arthodesis of the subastragaloid joints, are usually preferred. In the other types of cavus, in the early stage, section of the plantar structures with forcible correction may overcome the deformity. However, this is usually to be combined with a wedge-shaped osteotomy of the midtarsal articulation and subastragaloid arthrodesis, to give a solid base of support. Thus far, surgical treatment of the primary cause, such as spina bifida occulta, has not proved very successful in arresting the foot deformity, but further experience is necessary before a conclusion is reached.

The Use of Boiled Beef Bone Intramedullary Pegs in the Fractures of Long Bones: An Experimental Study.—Davison and Christopher [63] report a series of twenty-eight experiments undertaken to determine the fate of the boiled beef bone peg as an intramedullary splint. They came to the following conclusions: 1. That part of the boiled beef bone peg which remains in aseptic stable contact with the endosteum of its host, surrounded by living bone, becomes solidly imbedded in new bone. The peg gradually undergoes absorption and is replaced by new living bone, which in turn is later absorbed. 2. That part of the beef bone lying between fragments, but not protected by endosteum and not covered by living bone even with aseptic surroundings, undergoes rapid absorption and disintegration, and is not replaced by new living bone. 3. When one end of the beef bone peg is not fixed in stable contact with the endosteum, but remains in position, there is absorption of both the peg and the surrounding live bone. 4. The internal callus, when the mechanical fixation holds and is aseptic, is limited by the beef bone peg and does not bridge the line of fractures. The external callus is markedly lessened. The permanent or definitive callus is inhibited. 5. This series of experiments did not produce a single successful anatomic or functional result. 6. The causes of failure were: (*a*) infection, which was of frequent occurrence and usually fatal; (*b*) disengagement of the peg, due to failure in the mechanical reduction, lack of continued immobilization, and loosening of the repair by absorption of the peg and the surrounding live bone; (*c*) disintegration of the peg from absorption at the line of fracture. A repair apparently mechanically perfect would show a good result as long as the leg remained strong enough to sustain the bone. When disintegration of the peg occurred at the line of fracture a point of mobility would be found. The end-results were either permanent nonunion or lateral union, usually in malposition.

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63. Davison, C., and Christopher, F.: Surg., Gynec., & Obst. **38**:534 (April) 1924.

AMPUTATIONS

Sleeve Amputation of Thigh.—Wheeler [64] advocates the use of the "sleeve" method of amputation in severe complicated fractures requiring removal of the limb. The procedure is designed to meet certain urgent indications with the least possible surgical risk, and with a view to conserving the longest possible stump. The orthodox method of obtaining healthy flaps above the injury is abandoned, and the amputation is performed at a much lower level than most textbooks sanction. The operation follows the same lines as those suggested by Sampson Handley. It is unnecessary to divide the bone with the saw in a case of fracture, and the sleeve is left completely open for drainage and contraction. It requires only about fifteen minutes, and is applicable to any level of the upper or lower limb.

[ED. NOTE.—The "sleeve" amputation is a modification of the guillotine amputation, but differs from the latter in the essential point that the tissues are sectioned at a much lower level than the bone. Operative rectification of the stump is usually required at a later period, but this disadvantage, as well as that of the large open wound, is small in comparison with the advantage of increased length of the stump and the gain in functional power which that usually provides.]

RESEARCH

Haas [65] has made a very interesting report on the importance of periosteum and endosteum in the repair of transplanted bone. It is a report of well planned and carried out experimental work on dogs. In three series of experiments done on the metacarpal bone, which was fractured in all instances, deprived of its periosteum in some, of its endosteum in some, transplanted to the muscles of the back in a number, reimplanted in its own site in others, Haas has reached a valuable set of conclusions. The most significant of his conclusions is perhaps this: "In order to attain a maximum of reparative power in any bone lesion, it is deemed essential to preserve the integrity of both the periosteum and the endosteum." Haas found that his experiments in all instances where both the periosteum and endosteum were removed, the transplanted bones failed to show union in whatever site they were placed. He believes that the chief source of osteogenic cells, which work for repair of fractures, are from the periosteum and the endosteum; those of the periosteum are the most important, but the presence of either is sufficient for union.

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64. Wheeler, W. I., de C.: Practitioner **111**:309 (Nov.) 1923.

65. Haas, S. L.: Importance of the Periosteum and the Endosteum in the Repair of Transplanted Bone, Arch. Surg. **8**:535 (March) 1924.

[ED. NOTE.—Haas has demonstrated by careful experiment a rather well established clinical point of view. The editors do not believe, however, that these experiments give more than one phase of the question of nonunion after fracture. Haas makes one conclusion which his own experiments do not justify: namely, "Cases of nonunion not due to mechanical tissue interference or gross malposition of fragments must find their explanation in factors that inhibit simultaneously osteogenesis in both the periosteum and the endosteum." It seems to the editors that this is doubtless true, but it has not been demonstrated by experiment, and it is with these factors that we are particularly concerned.]

Phemister [66] has studied the causes of and the changes in loose bodies in the joints, and arrives at the conclusion that a satisfactory explanation of these loose bodies is still to be found. Pathologically, there takes place both regenerative and degenerative processes in the loosened body. While it is still attached by a pedicle, proliferative change is more marked than when detached. These bodies present fibrocartilage with calcification and a resultant pathologic type of new bone formation. They seem to be nourished in part by the synovial fluid. They seem not to be dependent on intra-articular fracture or subchondral fracture for their origin, though it seems possible that a fracture of the articular cartilage might exist for a long period of time without symptoms, as the articular cartilage is devoid of nerve supply.

Axhausen [67] has experimented with the healing of injuries to the articular cartilage. He has removed with a chisel flat pieces of cartilage and pyramidal shaped pieces, and reinserted them in the wound of the cartilage caused by the chisel. These injuries he describes as healing histologically in a perfect manner. He does not believe, with Barth, Bier, and others, that the synovial fluid contains an hormone that acts against the healing of injuries to the cartilage.

[ED. NOTE.—The editors feel that much confusion may arise in the experimental work done on cartilage and in the interpretation of results unless those working in this field recognize the fundamental characteristics of the different types of cartilage that exist in the make up of the joints of the human body.]

Burkhardt,[68] along with Phemister, calls attention to the fact that an injury to the articular cartilage may produce no symptoms, due to the lack of nerve supply in the cartilage. He has experimented with cadavers, and has found that it is possible to produce an extraordinary pressure on the medial condyle of the femur by holding the patella in

66. Phemister, D. B.: J. Bone & Joint Surg. **6**:278 (April) 1924.
67. Axhausen, G.: Arch. f. klin. Chir. **126**:96, 1923.
68. Burkhardt, H.: Beitr. z. klin. Chir. **130**:163, 1923.

certain positions. He could not actually produce fracture of the cartilage in this way, but he believes that the measurements of pressure made by the patella on the condyle make it a possible explanation.

Magnus [69] has made further studies into the question of the lymphatic vessels of the joints associated with his study of the lymphatics of the abdominal cavity. He has injected joints with hydrogen peroxid, and concludes that the articular cartilage has no lymphatics at all. The endothelial covering of the capsule has no connection with the abundant system of lymphatics contained within the fibrous part of the capsule. Therefore, the synovial cavity is not connected with the lymphatic system of the body. He concludes from these observations that it is clear why there is no excess of fluid in the joints in general anasarca or edema.

MISCELLANEOUS

A New Method of Correction of Structural Lateral Curvature of the Spine.—Lovett and Brewster [70] make a preliminary report on the treatment of structural scoliosis by means of a plaster jacket split horizontally on the side opposite the convexity of the curvature. A turn buckle is incorporated in the jacket, by which the split may be opened and a hinge incorporated on the side of the convexity. Thus, with a firm hold of the jacket on the pelvis and as high a grip as possible on the thorax, the two ends of the arc of the curve are separated with the fulcrum at the apex of the curve. Thus, instead of applying the correcting force at the centre of an arch, such as is done in most of the other forcibly correcting appliances, the force is applied at the two ends. The center of an arch is its most resistant point. By a push on the two ends, the most efficient force is applied to open the arch. Roentgenograms of several comparatively mild cases are shown, in which overcorrection for the moment has been obtained, and not only overcorrection of the lateral curve, but also correction of the rotation as well. The authors make no extravagant claim for the method, but believe it to be the most efficient that they have tried. They say its widest use is in moderate curves whose apex is below the mid dorsal region, but they believe this principle may be utilized in higher curves. They have been impressed by the rapidity with which the correction has been obtained.

Mechanics of the Normal and "Flat" Foot.—Morton,[71] after extensive anthropologic studies, discusses the evolution of the human foot and the mechanics of its various joints and muscle pulls. He stresses

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69. Magnus: Arch. f. klin. Chir. **126**:38, 1923.

70. Lovett, R. W., and Brewster, A. H.: Correction of Structural Lateral Curvature of the Spine. J. A. M. A. **82**:1115 (April 5) 1924.

71. Morton, D. J.: J. Bone & Joint Surg. **6**:368 (April) 1924.

the importance of the posture of the os calcis as the determining factor in the distribution of the body weight. If this is faulty, pronation of the foot starts a vicious circle, which restoration of muscle balance alone is often incapable of breaking. Metal arch supporters he looks on as temporary aids, and describes an efficient, small os calcis prop for this purpose. Operative procedures may well be undertaken in certain obstinate cases.

Absence of Pulsation in the Dorsalis Pedis Artery.—Schneyer [72] has investigated the presence and absence of pulsation in the dorsalis pedis artery and their relationship to intermittent claudication. Erb's statement that the absence of pulsation is an important pathologic sign, he believes must be viewed with certain reservations. He has examined about 500 patients in a Vienna hospital, and is convinced that many factors must be considered in interpreting its importance. These factors are sex, season, anatomic variations, a thick panniculus, adiposus, and vaso motor conditions. Women are more susceptible to vaso motor influences, and yet the phenomenon of intermittent claudication is very infrequently observed in the female sex. In thirty-one of eighty-two women of the gynecologic clinic whom he examined, no pulsation could be felt. In arteriosclerotic patients, the pulsation was rarely absent.

Intervertebral Compression of the Spinal Nerves.—An editorial [73] in the Journal of the American Medical Association is timely, calling attention to the caution which must be observed in the interpretation of symptoms of pain in the lower limbs as a sign of intervertebral compression of the spinal nerves by a sliding or slight displacement of the articular processes. It is obvious that complete dislocation will produce such pressure and crush the contents of the intervertebral canal, causing interruption of function, loss of sensation, and paralysis. The sliding of the intervertebral surfaces on one another actually widens the foramina and leaves no room for the exaggeration or exploitation of the results of partial subluxation. True pressure caused by the destructive changes of tuberculosis or other bone disease, by spinal tumors, and bony overgrowths gives rise to definite symptoms of local pain, spasm of the lumbar muscles, limitation of motion, altered posture, and sometimes to a diminution of power and altered reflexes.

[ED. NOTE.—A recent, very careful piece of work of Danforth and Wilson, which will be more carefully reviewed in a subsequent Report of Progress, seems to prove these same facts. They have employed the epidural injections of the harmless radiopaque lipoidal solution of Forestier and Sicard, which aids greatly in the interpretation of roentgenograms.]

72. Schneyer: Deutsche med. Wchnschr. **50**:109 (Jan. 25) 1924.
73. Editorial. J. A. M. A. (Jan. 5) 1924.

Free Nerve Transplants.—Chiasserini [74] gives the results in a series of experiments with free nerve transplants. His conclusions are: 1. Free transplants of nerves from the same species (homo-transplants), using nerves preserved in alcohol, become attached without causing any special reaction. 2. New nerve fibers develop in them fairly rapidly from the elements in the central stump. 3. Many months are required before the formation of new fibers reaches its maximum. 4. With the formation of the new fibers there is a corresponding improvement in the symptoms of motor deficiency and finally a disappearance of the motor deficiency. The transplant becomes sensitive to electrical stimulation. The observations in regard to heterotransplants were too few to allow of definite conclusions. The author states that, from his experience, one may believe that transplants of preserved nerves can succeed, provided certain rules are followed: 1. The homo-transplants are preserved in from 60 per cent. to 70 per cent. alcohol for not too long (the time is not stated). 2. The transplant is washed at length in water before it is used (one quarter of an hour is given as the time). 3. Careful hemostasis is done. 4. The transplant must be of a size not less than that of the injured nerve. 5. Suture is to be of the perineurium with needle and silk of Carrel. 6. Tubulization is not to be used at the original suture. If no evidence of success is present after two or three months and exploration shows adhesions, tubulization may be done then.

The Remote Results of Operations for Injuries of the Peripheral Nerves.—Platt and Bristow,[75] whose personal experiences with nerve suture during the war were very large, have contributed an important and very thorough article on the late results of operations for the repair of nerve injuries. Their summary is as follows: 1. The results of end-to-end suture. The results of end-to-end suture in the case of gunshot lesions are for the most part imperfect both from a neurologic and economic standpoint. In an average large series of consecutive operations, complete recovery will be found in about 20 per cent. The musculospiral nerve heads the list of recoveries and may be expected to show practically complete restoration of function in at least 50 per cent. of the successful cases. The ulnar and median nerves give disappointing results on the whole. In the former, complete recovery in the intrinsic muscles of the hand is so rare as to be almost unknown; in the cases showing recovery, neurotization of the hypo thenar muscles alone is fairly constant. The economic results, however, in this nerve are often good, except in individuals whose occupation demands the finer coordinated movements of the fingers. In the median, the sensory recovery is always inadequate, and this factor is the cause of the great

74. Chiasserini, A.: Policlinico **30**:489 (Oct. 15) 1923.
75. Platt, H., and Bristow, W. R.: Brit. J. Surg. **11**:535 (Jan.) 1924.

depreciation in the function of the hand. In sutures of the median in the forearm, complete failure of recovery in the thenar muscles is frequently seen. The results of sciatic nerve sutures are poor, and a considerable number of such limbs ultimately come to amputation. 2. The outstanding cause of failures or imperfections are, aside from delay or gross errors in operative technic: (*a*) changes in the nerve above the line of suture, either interstitial fibrosis or an ascending neuritis, due in either case to wound infection; (*b*) topographical confusion in regeneration. 3. The operations of indirect nerve repair (with the possible exception of nerve grafting) have proved ineffective, and should be eliminated from the repertoire of peripheral nerve surgery. Investigation of the results of a small number of nerve grafting operations in this country suggests that these procedures are of limited value. 4. In the nerve lesions associated with profound irritation (causalgia), resection and suture or the intraneural injection of 70 per cent. alcohol will rarely fail to bring about immediate and complete relief of the pain, but at the cost of the signs and symptoms associated with complete division of that nerve. In conclusion, "We wish to make it clear that, although a fair and critical survey of the nerve injuries of the war must leave us pessimistically inclined, yet there is a brighter side to the picture. War injuries are complicated by sepsis; but the prognosis for the nerve injuries of civil life must be vastly better and the experience gained in nerve surgery on the scale which has been possible will help to crystallize our ideas for the benefit of the patient and for the improvement in surgical teaching."

At this point follows a summary of the discussion held at the Sixth Congress of the International Society of Surgery in July, 1923. The experience of the American and British surgeons was exactly parallel. Both these and the Continental surgeons all agreed that there was need of the segregation of these patients under the care of surgeons experienced in this branch of surgery, and under conditions where prolonged and careful postoperative treatment could be carried out. The advantages of early operation were emphasized by all, and there was general agreement that resection and end-to-end suture was the operation of choice in every case of nerve injury where the nerve was divided or badly damaged. If direct end-to-end suture was not possible, the American and British surgeons supported the two-stage operation, while the Continental surgeons utilized one or the other of the various methods of grafting to bridge the gap. They preferred, if possible to use the autogenous graft, but they placed more reliance on the results of this method than we believe is warranted by the statistics quoted. It was generally felt that, if the nerve bed was not satisfactory, transposition into a new intramuscular bed was all that was needed. A stimulating atmosphere was introduced into the discussion by the vivid contribution

of Leriche, in which he strongly urged the most general adoption of his operation of periarterial sympathectomy. He insisted on its value in dealing with causalgia, trophic changes, and in fact all cases with the signs of nerve irritation. The inherent objection to the rationale of the operation at the present time is its lack of sound anatomic basis. While much remains to be worked out concerning the distribution of the sympathetic fibers of the limbs, it is quite certain that the mass of these fibers does not form a continuous chain localized in the sheath of the main artery over the whole of its course.

On the whole, it was felt that the results of nerve suture in the case of war wounds were disappointing. In many instances, however, it has been encouraging to find that they tended to improve after long intervals. Infection was the outstanding factor in the production of failures, and for this reason, the prognosis in the nerve injuries occurring in civil life must always be markedly better.